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SMITHSONIAN INSTITVTION

WASHINGTON 1846

SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 53

CAMBRIAN
GEOLOGY AND PALEONTOLOGY

I

BY

CHARLES D. WALCOTT

"EVERY MAN IS A VALUABLE MEMBER OF SOCIETY WHO, BY HIS OBSERVATIONS, RESEARCHES, AND EXPERIMENTS, PROCURES KNOWLEDGE FOR MEN"—SMITHSON

(PUBLICATION 1949)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
1910

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In the Smithsonian Contributions to Knowledge, as well as in the present series, each article bears a distinct number, and is also separately paged unless the entire volume relates to one subject. The actual date of the publication of each article is that given on its special title-page, and not that of the volume in which it is placed. In many cases papers have been published and largely distributed, several months before their combination into volumes.

CHAS. D. WALCOTT,
Secretary of the Smithsonian Institution

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The list on pages 351-371 may be regarded as a completely cross-referenced index to the synonymy of the Mesonacidæ, and only the actual references as they occur in the synonymy will be found in this index.

[1] The number in heavy-faced type refers to the page upon which the species is described.

[1] Included by mistake with the figure (9*a*) representing *Obolus smithi*.

[1] Figure 9 represents a specimen of *Micromitra (Paterina) major*, which was included by mistake.

SMITHSONIAN MISCELLANEOUS COLLECTIONS

PART OF VOLUME LIII

CAMBRIAN GEOLOGY AND PALEONTOLOGY

No. 1.—NOMENCLATURE OF SOME CAMBRIAN CORDILLERAN FORMATIONS

BY

CHARLES D. WALCOTT

No. 1804

CITY OF WASHINGTON

PUBLISHED BY THE SMITHSONIAN INSTITUTION

April 18, 1908

CAMBRIAN GEOLOGY AND PALEONTOLOGY

No. 1.—NOMENCLATURE OF SOME CAMBRIAN CORDILLERAN FORMATIONS

By CHARLES D. WALCOTT

In connection with the preparation of the section on the stratigraphic distribution of the Cambrian Brachiopoda for Monograph LI, of the U. S. Geological Survey, I find that it is necessary to refer to many undefined Cambrian formations of the Cordilleran area. The present paper is published for the information of geologists and for the purpose of properly defining and characterizing the formations in question, as the first reference to these formations should be accompanied by more information than can well be included in the pages of the monograph.

CANADIAN ROCKY MOUNTAINS

Since reading, in 1886, Mr. R. G. McConnell's report of 1885 on his section across the Rocky Mountains in the vicinity of the 51st parallel,[1] I have had a strong desire to study the stratigraphy of the Cambrian portion of the section. It was not until the summer of 1907 that the opportunity came. Accompanied by Mr. Lancaster D. Burling as field assistant, a study was made of the typical Castle Mountain section of Mr. McConnell, the lower portion of the Mt. Stephen and Mt. Whyte sections, and the full section of Mt. Bosworth, on the Continental Divide, which proved to be the most complete.

Except where otherwise stated, the sections were carefully measured with rod and clinometer. The strata were so well exposed that it was rarely necessary to go any distance to avoid talus slopes and covered portions of the section. Collections of fossils were made at many horizons, but, owing to the limited time available, this part of the work was neither systematic nor exhaustive.

Location.—The area examined is on the line of the Canadian Pacific Railway between the Sawback Range on the east and the Van Horn Range on the west. In this limited area there was only time for the examination and measurement of the strata of Castle Mountain and Mt. Bosworth, the lower 3,800 feet of the Mt. Stephen section, and the Lower Cambrian formations on the slopes of Mts. Whyte and St. Piran, in the vicinity of Lakes Louise and Agnes.

[1] Geol. and Nat. Hist. Survey of Canada, Ann. Rept., 1886, Part D, pp. 15D–30D, 1887.

FUTURE WORK.—It is desirable that the Lower Cambrian strata of Fairview and Saddle Mountains near Laggan should be studied carefully; also that the area northwest of Mt. Bosworth and west of Mt. Daly should be examined for Upper Cambrian and Lower Ordovician formations and fossils. Exhaustive collections should also be made at many stratigraphic horizons.

NOMENCLATURE.—Mr. McConnell proposed the name "Castle Mountain Group" for the great series of limestones and shales between the quartzitic sandstones and siliceous shales of the "Bow River Group" below and the superjacent Ordovician graptolitic shales on the west and Banff limestone on the east. This includes the upper portion of the Lower Cambrian fauna at the base and the lower portion of the Ordovician fauna at the summit. The term "Castle Mountain" is useful for the series, but I think that local names can be applied with advantage to several of the formations of the "Castle Mountain Group" as originally defined. The following table gives the relative positions and thicknesses of the new formation names herein proposed and defined for the Canadian Rocky Mountain section:

	Thickness (in feet).		
	Mt. Stephen.	Mt. Bosworth.	Castle Mt.
Upper Cambrian:			
Sherbrooke formation...	0	1,360	0
Paget formation.........	0	360	0
Bosworth formation.....	Not measured	1,855	0
Middle Cambrian:			
Eldon formation........	Not measured	2,733	2,195
Stephen formation	562	640	366
Cathedral formation.....	1,600–1,800	1,595	987
Mt. Whyte formation....	315	390	248
Lower Cambrian:			
St. Piran formation......	300 +	300 +	500+
Lake Louise formation ..	......	......	......
Fairview formation......	......	......	......

SHERBROOKE FORMATION

TYPE LOCALITY.—Western slopes of Mt. Bosworth, overlooking Sherbrooke Lake, Canadian Rocky Mountains, five miles north of Hector, on the Canadian Pacific Railway, British Columbia.

DERIVATION.—From Sherbrooke Lake, below the typical locality.

CHARACTER.—Bluish gray, arenaceous, dolomitic, massive, and thin-bedded to shaly limestones, with a few oolitic layers and cherty inclusions.

THICKNESS.—At Mt. Bosworth, 1,360 feet.

ORGANIC REMAINS.—Upper Cambrian, passing at summit into Ordovician.

PAGET FORMATION

TYPE LOCALITY.—Southeastern slope of Paget Peak, beneath the Sherbrooke formation, which forms the high cliffs of Paget Peak and Mt. Daly. The Paget formation breaks down more readily than the Sherbrooke, presenting a slightly broken cliff line. The most accessible locality found is on the east face of the west ridge of Mt. Bosworth (Sherbrooke ridge).

DERIVATION.—From Paget Peak, the type locality.

CHARACTER.—Bluish gray and oolitic limestones, usually thin bedded.

THICKNESS.—At Mt. Bosworth, 360 feet.

ORGANIC REMAINS.—Upper Cambrian fauna.

BOSWORTH FORMATION

TYPE LOCALITY.—Ridge extending northwest from Mt. Bosworth, and southeast base of Paget Peak and Mt. Daly.

DERIVATION.—From Mt. Bosworth, the type locality.

CHARACTER.—Arenaceous, dolomitic limestones, massive, thin bedded, and shaly, with bands of purple and gray siliceous shales.

THICKNESS.—At Mt. Bosworth, 1,855 feet.

ORGANIC REMAINS.—None observed; formation referred to Upper Cambrian.

ELDON FORMATION

TYPE LOCALITY.—Upper massive limestones of Castle Mountain, Canadian Rocky Mountains, Province of Alberta, one to two miles north of Eldon Switch, on the Canadian Pacific Railway.

DERIVATION.—From Eldon, opposite the type locality.

CHARACTER.—Massive, arenaceous, dolomitic limestones, with a few bands of purer bluish gray limestone.

THICKNESS.—In Mt. Bosworth section, 2,733 feet; at Castle Mountain, 2,195 feet.

ORGANIC REMAINS.—Middle Cambrian.

STEPHEN FORMATION

TYPE LOCALITY.—Bluish gray and greenish gray limestone and shale band about 2,700 feet up above railroad track on the north and east sides of Mt. Stephen, Canadian Rocky Mountains, British Columbia, above Field, on the Canadian Pacific Railway.

Derivation.—From Mt. Stephen, the type locality.

Character.—Limestones and shales, calcareous and siliceous.

Thickness.—In Mt. Bosworth section, 640 feet; on Mt. Stephen, 562 feet, with 150 feet of local development of Ogygopsis shales at the summit.

Organic Remains.—Middle Cambrian: Ogygopsis fauna of Mt. Stephen and fauna below in the thin-bedded, dark bluish gray limestone.

Cathedral Formation

Type Locality.—Cathedral Mountain and Cathedral Crags, east of Mt. Stephen and southeast of Mt. Bosworth.

Derivation.—From Cathedral Mountain, the type locality.

Character.—Massive arenaceous and dolomitic limestone.

Thickness.—In Mt. Bosworth section, 1,595 feet; in Castle Mountain, 987 feet; in Cathedral Mountain and Mt. Stephen, 1,600-1,800 feet.

Organic Remains.—Middle Cambrian.

Mt. Whyte Formation

Type Locality.—Mt. Whyte, above Lake Agnes, and eastern slope of Popes Peak, southwest of Mt. St. Piran.

Derivation.—From Mt. Whyte, the type locality.

Character.—Alternating bands of limestone and siliceous and calcareous shale.

Thickness.—North slope of Mt. Whyte, 386 feet; south slope of Mt. Bosworth, 390 feet; Mt. Stephen, above railroad tunnel, 315 feet; southeast slope of Castle Mountain, 248 feet.

Organic Remains.—Lower Cambrian.

BOW RIVER GROUP

This name was proposed by Dr. George M. Dawson for the great series of arenaceous and siliceous strata beneath the Castle Mountain group of McConnell. This series will ultimately be divided into several formations. At present the upper portion may be separated into three formations in the vicinity of Lake Louise.

St. Piran Formation

Type Locality.—Southeast slope of Mt. St. Piran. The basins of Lakes Agnes and Mirror are both excavated in this formation.

DERIVATION.—From Mt. St. Piran, the type locality.

CHARACTER.—Mainly gray, quartzitic sandstones, with a few bands of siliceous shale.

THICKNESS.—At Mt. St. Piran, 2,640 feet.

ORGANIC REMAINS.—Lower Cambrian in the upper portion.

LAKE LOUISE FORMATION

TYPE LOCALITY.—On both sides of Lake Louise, at its upper end; well shown on the northwest and north sides of Fairview Mountain.

DERIVATION.—From Lake Louise, the type locality.

CHARACTER.—Siliceous shales.

THICKNESS.—At upper end of Lake Louise, 105 feet.

ORGANIC REMAINS.—Lower Cambrian.

FAIRVIEW FORMATION

TYPE LOCALITY.—Northeast slope of Fairview Mountain.

DERIVATION.—From Fairview Mountain, the type locality.

CHARACTER.—Gray, quartzitic sandstones.

THICKNESS.—On east slope of Fairview Mountain, 1,000 + feet.

ORGANIC REMAINS.—Unknown. No attempt was made to find fossils in this formation.

NORTHEASTERN UTAH AND SOUTHERN IDAHO

The section in Blacksmith Fork Canyon was first measured by Mr. F. B. Weeks, assisted by Mr. L. D. Burling, in a general reconnaissance of the northeastern and central parts of Utah made in 1905. In 1906 I established a permanent camp in the canyon and, assisted by Mr. L. D. Burling, spent nearly two months in detailed work upon the section and its faunas.

Near the close of the summer, camp was moved to Mill Canyon, in the Bear River Range, about 5 miles west of Liberty, Bear Lake County, Idaho, where Mr. R. S. Spence, of Evanston, Wyoming, had discovered a remarkable deposit of lower Middle Cambrian fossils. The section at this point was measured and found to agree quite closely with that in Blacksmith Fork; and the shale, which contained the rich fauna discovered by Mr. Spence, was called the Spence Shale horizon of the Ute formation from Spence Gulch, in which it has its great local development.

The following table gives a summary of the new formations defined, together with their thicknesses in each of the sections:

	Thickness (in feet).	
	Blacksmith Fork.	West of Liberty.
Upper Cambrian:		
St. Charles formation	1,225	1,197
Middle Cambrian:		
Nounan formation	1,041	814
Bloomington formation	1,320	1,162
Blacksmith formation	570	23
Ute formation	759	731
Spence shale	30	30
Langston formation	107	30
Brigham formation	1,250+	1,000+
	6,662	4,997

St. Charles Formation

Type Locality.—Bear River Range, west of the town of St. Charles, in the Bear Lake Valley, Bear Lake County, Idaho. The most accessible locality is in Blacksmith Fork Canyon, east of Hyrum, Cache County, Utah.

Derivation.—From the town of St. Charles, near the typical locality. The stream flowing through St. Charles passes over the formation.

Character.—Bluish gray to gray, arenaceous limestones, with some cherty and concretionary layers, passing at the base into thin-bedded gray to brown sandstones.

Thickness.—In Blacksmith Fork Canyon, 1,225 feet; in the section west of Liberty, 1,197 feet.

Organic Remains.—Upper Cambrian, passing at the summit into Ordovician.

Nounan Formation

Type Locality.—Bear River Range, east slope of Soda Peak, west of the town of Nounan, in the Bear Lake Valley, Bear Lake County, Idaho. The most accessible locality is in Blacksmith Fork Canyon, east of Hyrum, Cache County, Utah.

Derivation.—From the town of Nounan, near the typical locality, Nounan Creek Canyon cuts through the formation.

Character.—Limestones. Light gray to dark lead-colored, arenaceous limestones.

THICKNESS.—In Blacksmith Fork Canyon, 1,041 feet; in the section west of Liberty, 814 feet.

ORGANIC REMAINS.—A few traces of Middle Cambrian fossils in the lower part and numerous annelid borings throughout.

BLOOMINGTON FORMATION

TYPE LOCALITY.—Bear River Range, about 6 miles west of the town of Bloomington, Bear Lake County, Idaho. A second easily accessible locality is in Blacksmith Fork Canyon, east of Hyrum, Cache County, Utah.

DERIVATION.—From Bloomington Creek, which is near the type locality, and passes through the formation.

CHARACTER.—Bluish gray, more or less thin-bedded limestones and argillaceous shales. Small rounded nodules of calcite occur scattered irregularly through many of the layers of limestone.

THICKNESS.—In Blacksmith Fork Canyon, 1,320 feet; in the section west of Liberty, 1,162 feet.

ORGANIC REMAINS.—Abundant Middle Cambrian fossils.

BLACKSMITH FORMATION

TYPE LOCALITY.—In Blacksmith Fork Canyon, about 8 miles above its mouth and 15 miles east of Hyrum, Cache County, Utah.

DERIVATION.—From Blacksmith Fork, the type locality.

CHARACTER.—Gray arenaceous limestone in massive layers.

THICKNESS.—In Blacksmith Fork, 570 feet; in the section west of Liberty, 23 feet.

ORGANIC REMAINS.—Large, irregular annelid borings. Middle Cambrian age shown by position in section.

UTE FORMATION

TYPE LOCALITY.—Slopes of Ute Peak, near the forks of East Fork, east of Paradise, Cache County, Utah. This formation was given the name Ute limestone by the Fortieth Parallel Survey, but aside from the fact that it was stated to overlie the Cambrian quartzites and to be composed of 2,000 feet of limestones containing Cambrian fossils, it was not defined or limited. The beds here referred to the Ute formation contain the fossils mentioned by the Fortieth Parallel Survey as characterizing the lower portion of the Ute limestone. The formation is very easily accessible in Blacksmith Fork Canyon.

DERIVATION.—From Ute Peak, the type locality.

CHARACTER.—Blue to bluish gray, thin-bedded, fine-grained limestones and shales, with some oolitic, concretionary, and intraformational conglomerate layers.

THICKNESS.—In Blacksmith Fork, 759 feet; in the section west of Liberty, 731 feet.

ORGANIC REMAINS.—Abundant Middle Cambrian fossils.

SPENCE SHALE

TYPE LOCALITY.—Spence Gulch, a ravine running up into Danish Flat from Mill Canyon, about 5 miles west-southwest of Liberty, Bear Lake County, Idaho. This shale occurs at the base of the Ute formation.

DERIVATION.—From Spence Gulch, the type locality.

CHARACTER.—Argillaceous shales.

THICKNESS.—In the section west of Liberty, 30 feet; in Blacksmith Fork, 30 feet.

ORGANIC REMAINS.—An extremely abundant and varied lower Middle Cambrian fauna.

LANGSTON FORMATION

TYPE LOCALITY.—The most readily accessible locality for this formation is in Blacksmith Fork, but the strike of the beds (as shown on the eastern half of Map 3 of the Fortieth Parallel Survey) carries the formation into the valley of Langston Creek, and the formation is given that name.

DERIVATION.—From Langston Creek.

CHARACTER.—Massive bedded, bluish gray limestone with many round concretions.

THICKNESS.—In Blacksmith Fork, 107 feet; in the section west of Liberty, 30 feet.

ORGANIC REMAINS.—Lower Middle Cambrian fauna.

BRIGHAM FORMATION

TYPE LOCALITY.—West front of the Wasatch Range, northeast of Brigham, Box Elder County, Utah.

DERIVATION.—From Brigham, near the type locality.

CHARACTER.—Massive quartzitic sandstones.

THICKNESS.—At Brigham, 2,000+ feet; in Blacksmith Fork, 1,250 feet; and in the section west of Liberty, Idaho, 1,000+ feet.

The Brigham formation is the overlapping shore deposit of Middle Cambrian time along what is now the Wasatch Range. To the northwest, in the Belt Mountain region of Montana, the upper part

of the same relative horizon is called the Flathead sandstone. As the strata are followed to the northwest, the sandy beds occupy a lower stratigraphic horizon until on Gordon Mountain, at the head of the South Fork of the Flathead River, in Montana, the sandstones are of lower Middle Cambrian age. The Brigham formation should not be confused with the much older Prospect Mountain "quartzite" formation of central Nevada, which is of Lower Cambrian age.

ORGANIC REMAINS.—Annelid trails and trilobite tracks. Characteristic Middle Cambrian fossils were found in the upper portion of this formation west of Liberty, Bear Lake County, Idaho.

HOUSE RANGE, UTAH

The section exposed in the House Range was first studied by Dr. G. K. Gilbert, who made small collections of fossils from various horizons. These collections were so interesting that I visited the range in 1903. In 1905 I revisited the range, in company with Messrs. F. B. Weeks and L. D. Burling, measured the entire section carefully, and made further large collections of fossils. The section extends from well down in the Lower Cambrian to the base of the Ordovician, and is the best and most complete of the Basin Range sections so far studied. A map will be published with the detailed sections, giving the geographic localities referred to in the nomenclature of the formations of the House Range section.

The following table gives the relative positions and the thickness of the various formations defined in the following pages:

	Feet
Upper Cambrian:	
Notch Peak formation	1,890
Orr formation	1,825
Middle Cambrian:	
Weeks formation	1,390
Marjum formation	1,092
Wheeler formation	570
Swasey formation	238
Dome formation	355
Howell formation	640
Lower Cambrian:	
Pioche formation	125
Prospect Mountain formation	1,200+

NOTCH PEAK FORMATION

TYPE LOCALITY.—Upper portion of the main mass of Notch Peak, House Range, Utah.

Derivation.—From Notch Peak, the type locality.

Character.—Gray, arenaceous limestone in more or less massive layers.

Thickness.—1,890 feet.

Organic Remains.—Upper Cambrian fossils occur in the lower portion, and the formation extends in its upper portion to the Lower Ordovician.

Orr Formation

Type Locality.—Orr Ridge, a spur extending eastward from the main mass of Notch Peak, on the south side of Weeks Canyon, House Range, Utah.

Derivation.—From Orr Ridge, the type locality.

Character.—Gray, slightly arenaceous limestones and shales.

Thickness.—1,825 feet.

Organic Remains.—Upper Cambrian fossils; in its lower part the formation extends to the shales of the Weeks formation, which carry Middle Cambrian fossils.

Weeks Formation

Type Locality.—North side of Weeks Canyon, north of Orr Ridge, House Range, Utah.

Derivation.—From Weeks Canyon, the type locality.

Character.—Thin-bedded shaly limestones, with a few bands of oolitic and arenaceous limestones.

Thickness.—1,390 feet.

Organic Remains.—Middle Cambrian fauna.

Marjum Formation

Type Locality.—Cliffs on the south side of Marjum Pass, House Range, Utah.

Derivation.—From Marjum Pass, the type locality.

Character.—Gray to dark, more or less thin-bedded, arenaceous limestone.

Thickness.—1,092 feet.

Organic Remains.—Middle Cambrian fauna.

Wheeler Formation

Type Locality.—Center of Wheeler Amphitheater, southeast of Antelope Springs, House Range, Utah.

Derivation.—From Wheeler Amphitheater, the type locality.

CHARACTER.—Alternating bands of thin shaly limestone and calcareous shale.

THICKNESS.—570 feet.

ORGANIC REMAINS.—Middle Cambrian fauna.

SWASEY FORMATION

TYPE LOCALITY.—Slopes of Swasey Peak, House Range, Utah.

DERIVATION.—From Swasey Peak, the type locality.

CHARACTER.—Bluish gray, oolitic, and arenaceous limestone, with some calcareous and argillaceous shales.

THICKNESS.—238 feet.

ORGANIC REMAINS.—Middle Cambrian fauna.

DOME FORMATION

TYPE LOCALITY.—At the head of Dome Canyon, House Range, Utah.

DERIVATION.—From Dome Canyon, the type locality.

CHARACTER.—Massive bedded, gray siliceous limestone.

THICKNESS.—355 feet.

ORGANIC REMAINS.—No traces of fossils, but referred to the Middle Cambrian because both overlaid and underlaid by rocks containing a Middle Cambrian fauna.

HOWELL FORMATION

TYPE LOCALITY.—In slopes of Howell Peak, on the west side of the House Range, about 5 miles west of Antelope Springs, House Range, Utah.

DERIVATION.—From Howell Peak, the type locality.

CHARACTER.—Dark, more or less massive limestone and pinkish argillaceous shales.

THICKNESS.—640 feet.

ORGANIC REMAINS.—Middle Cambrian fauna.

PIOCHE FORMATION

TYPE LOCALITY.—Southeast of the town of Pioche, Nevada, on road to Panaca, Utah.

DERIVATION.—From Pioche, the type locality.

CHARACTER.—Arenaceous and argillaceous shaly layers with some thin layers and bands of limestone more or less irregularly interbedded and limited in horizontal distribution.

THICKNESS.—At Pioche, Nevada, 210 feet. On the west face of the Highland Range, 18 miles west of Pioche, this formation

is 170 feet thick. In the Eureka District of Nevada, 135 miles northwest of Pioche, this formation lies between the Prospect Mountain quartzitic sandstone and the great limestone series and is about 200 feet in thickness. In the House Range section, 105 miles north-northeast of Pioche, the formation is 125 feet thick. In the Big Cottonwood section of the Wasatch range, about 125 miles northeast of the House Range, near the old shore line, the Pioche formation is represented by the lower portion of the arenaceous shales which are here 250 feet in thickness. The Pioche formation horizon is next met with to the north where the line of the Canadian Pacific railroad crosses the Continental Divide. At this place the formation is called the Mount Whyte formation.

ORGANIC REMAINS.—At all the localities mentioned except that of the House Range, where no fossils except annelid borings and trails have been found, the Lower Cambrian Olenellus fauna occurs.

PROSPECT MOUNTAIN FORMATION[1]

TYPE LOCALITY.—Prospect Peak, Eureka District, Nevada.

DERIVATION.—From Prospect Peak, the type locality.

CHARACTER.—Gray to brown quartzitic sandstones.

THICKNESS.—At Prospect Peak, 1,500 feet. Estimated 1,200 feet on the western face of the House Range, Millard County, Utah, in the vicinity of Dome and Sinbad Canyons.

ORGANIC REMAINS.—Annelid trails and trilobite tracks. Lower Cambrian in age.

[1] This formation was first named by Mr. Arnold Hague in 1882, in the Second Ann. Rept. U. S. Geol. Survey, p. 27, and defined in 1883, in the Third Ann. Rept. U. S. Geol. Survey, p. 254.

SMITHSONIAN MISCELLANEOUS COLLECTIONS

PART OF VOLUME LIII

CAMBRIAN GEOLOGY AND PALEONTOLOGY

No. 2.—CAMBRIAN TRILOBITES

WITH SIX PLATES

BY

CHARLES D. WALCOTT

No. 1805

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
April 25, 1908

CAMBRIAN GEOLOGY AND PALEONTOLOGY

No. 2.—CAMBRIAN TRILOBITES

By CHARLES D. WALCOTT

(WITH SIX PLATES)

CONTENTS

The monograph on the Cambrian Brachiopoda,[1] upon which I have been working for so long, is about ready for the press, and attention is now being given to the preliminary study of some of the American Cambrian trilobites. If students and collectors in any country know of interesting or new forms of Cambrian or Lower Ordovician trilobites, or of more perfect specimens representing previously described forms, I should very much like to have their coöperation in making this investigation as thorough and complete as possible.

This is the first of a series of brief papers that will be published as new material of interest is worked up. The classification of Dr. Charles E. Beecher[2] will be followed, in the preliminary studies at least, with such modifications as may appear necessary during the course of the investigations.

[1] To be published as Monograph LI of the U. S. Geological Survey.

[2] American Jour. Sci., 4th ser., vol. III, 1897, pp. 89–106, 181–207.

Order PROPARIA Beecher

BURLINGIDÆ, new family

Dorsal shield small, elongate, broad oval in outline. Cephalon about one-fourth the length, transversely semicircular; genal angle acute or spinose; glabella with transverse lobes. Free cheeks small, separate. Facial sutures cut the margin in front of the genal angles, extend in to the posterior portion of the eye lobe and outward from the anterior portion to the antero-lateral margin of the cephalon. Eyes of medium size, clearly defined.

Thorax with fourteen segments in the one species preserving them; pleuræ with flat, straight furrows.

Pygidium large, with strong axis and pleural lobes, or small and with medium axis and pleural lobes.

STRATIGRAPHIC RANGE.—Central portion of the Middle Cambrian to the *Agnostus pisiformis* zone of the Swedish Upper Cambrian.

OBSERVATIONS.—This family includes the genera *Burlingia* and *Schmalenseeia*.[1] The first is represented by entire specimens and the latter by the cephalon, fragments of the thorax, and entire pygidia. The facial sutures and free cheeks relate *Burlingia* to some forms of the Cheiruridæ, while the pygidium of *Burlingia* recalls the simple pygidium of *Paradoxides*, and the pygidium of *Schmalenseeia* recalls that of *Amphion*. The flat, straight furrowed pleuræ of the thorax of *Burlingia* recall the pleuræ of *Olenoides*. The assemblage of characters in *Burlingia* and *Schmalenseeia* clearly indicate a distinct family of the Proparia, more primitive than any other forms of that order.

BURLINGIA, new genus

Dorsal shield small, elongate, broadly oval. Cephalon semicircular; one-fourth the length of the entire shield; genal angles with spines; cranidium[2] with anterior and posterior limbs that extend outward from the glabella to the outer margin; glabella slightly convex, with indications of lobes. Free cheeks subquadrangular, small. Facial sutures extend from in front of the genal angles inward to the eyes and then obliquely outward and forward, cutting the antero-lateral margin. Eyes of medium size.

Thorax with fourteen segments; pleuræ with a flat, direct furrow; pleuræ extended into backward-curving, falcate extremities.

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[1] Moberg, 1903, Meddelande från Lunds Geol. Mineral. Inst. No. 5 (Geol. Fören. i Stockholm Förhandlingar, Bd. xxv, Häft 2, 1903, No. 219), p. 96.

[2] The cranidium includes all portions of the cephalon except the free cheeks and eye lobes.

Pygidium small, elongate, without defined segments.

Genotype.—*Burlingia hectori*, new species.

Observations.—This genus is represented by a single species from the central portion of the Middle Cambrian fauna. The only form with which it can be directly compared is *Schmalenseeia* Moberg,[1] which is represented by specimens of the cranidium, pygidium, and fragments of the thoracic segments belonging to a single species. The cranidium of *Schmalenseeia* differs in having a convex glabella divided into four lobes by four transverse furrows, and in the presence of a defined occipital segment. The fragments of the thorax illustrated by Dr. Moberg (1903, pl. IV) and his description of them indicate that the pleuræ were flattened and marked by shallow, direct furrows similar to those on the pleuræ of *Burlingia*. With the present information, it is in the pygidium that the great difference in the two genera is found. The pygidium of *Schmalenseeia* is large and it has a strong axial lobe divided into a number of segments; the pleural lobes are broad and marked by numerous backward-curving, flat furrows much like those of the thoracic segments of *Burlingia*. The pygidium of *Burlingia* is small and apparently without segments or pleural lobes; it is a simple plate as in *Paradoxides*.

Dr. Moberg (1903, p. 100) has noted the resemblance between the direction of the facial sutures of *Schmalenseeia* and those of some genera of the Cheiruridæ and Encrinuridæ, while the broad anterior margin of the head suggests some of the Conocoryphidæ; he concludes that these resemblances have little value, as the other parts of the shield differ so largely from the representatives of these genera. In this I agree with him. The two genera are unlike all other trilobites and form a family type by themselves.

The genus is named after Mr. Lancaster D. Burling, of the United States National Museum, who found the only three nearly entire specimens of this interesting trilobite.

BURLINGIA HECTORI, new species

Plate I, Figure 8

Dorsal shield small; longitudinally broad oval; slightly convex. Cephalon one-fourth the length of the complete dorsal shield, semicircular in outline, with genal angles prolonged into short slender spines that scarcely extend beyond the extremity of the first or anterior thoracic segment; the posterior margin of the cephalon is nearly

[1] Moberg, 1903, Meddelande från Lunds Geol. Mineral. Inst. No. 5 (Geol. Fören. i Stockholm Förhandlingar, Bd. XXV, Häft 2, 1903, No. 219), pp. 93-102, pl. IV.

transverse except at the axial lobe, where it arches slightly forward; the slope from the central portion of the cephalon to the margin is unbroken by any furrow and there is no clearly defined or raised rim. Cranidium with a broad campanulate frontal limb that extends from the anterior base of the eyes obliquely outward and forward and directly forward from the glabella to the outer margin of the cephalon; the posterior limbs, on their inner side, occupy the space between the posterior base of the eye and the posterior margin of the cephalon and extend outward to the lateral margin with a gradually increasing width; there is no fixed cheek between the palpebral lobe and the glabella; palpebral lobe about one-third the length of the cephalon and situated a little back of the center; it is slightly elevated along the outer margin and slopes toward the dorsal furrow next to the glabella. Glabella about three-fifths the length of the cephalon; it has subparallel sides up to the front of the eyes, where the sides curve inward and unite to form an obtusely rounded outline; in front the glabella merges into the frontal limb, so as to make it difficult to indicate a line of division between them; the glabella is gently convex and more or less clearly marked by a narrow median ridge, and, on each side of the ridge, two pits that indicate transverse furrows, very much as do the pits on the glabella of *Oryctocephalus*[1]; there is no trace of an occipital furrow or segment. Free cheeks subquadrangular in outline; on their inner margin they support the visual surface of the eye and from there slope gently to the outer margin. The facial sutures cut the lateral margin of the cephalon some distance in front of the genal angle and extend wth a little backward curvature to the posterior base of the eye; after curving over the eye lobe they extend obliquely forward at an angle of about 50° to the margin.

Thorax with fourteen segments; the first is nearly transverse, but each succeeding pleural lobe bends back a little more than the one preceding it, so that the pleural lobe of the posterior segment is bent back parallel to the side of the pygidium; the central axis of the thorax is gently convex, with a low median ridge that rises into a minute node on the two anterior segments; it gradually widens from the first to the seventh segment, and then narrows a little at each segment back to the pygidium; the pleural lobes are flattened between the axial lobe and the angle where the pleuræ bend more or less backward; each pleura has a broad, shallow, direct furrow that extends from the inner end out to the backward curving portion of the pleuræ; the edge of the furrow and of the segment is marked by

[1] Walcott, 1886, Bull. U. S. Geol. Survey, No. 30, p. 210.

a narrow thread-like ridge; the pleuræ terminate in falcate extremities; some of which, on the two anterior segments, appear to have a very short, fine spine at the posterior termination of each pleura.

Pygidium a narrow, elongate, moderately convex, central plate without defined segments or pleural lobes; it has a small node at the anterior third of its length. None of the specimens show the posterior margin; it may have been a single, broad spine or it may have terminated with a slightly arched posterior margin.

The outer surface of the dorsal shield appears to have been minutely granular or smooth.

DIMENSIONS.—The most perfect specimen of the dorsal shield has a length of 7 mm.; greatest width, 5 mm. The other dimensions are as follows:

	mm
Cephalon:	
Length	2.25
Width at posterior margin	4.74
Thorax:	
Length	1.75
Greatest width	5.00
Axial lobe, greatest width	1.50
Pleural lobe, greatest width	1.75
Pygidium:	
Length to line of contour of dorsal shield	1.50
Width at anterior end	.75

OBSERVATIONS.—This interesting trilobite has a cephalon much like that of *Schmalenseeia amphionura* Moberg,[1] but it differs in details, and the pygidium is quite unlike that of Dr. Moberg's species; the furrows and ridges on the pygidium of the latter are very similar to those of the thorax of *Burlingia*.

The stratigraphic horizon of this species is 2,400 feet above the Lower Cambrian or Olenellus fauna and 2,600 feet below the Upper Cambrian fauna. It is associated with *Zacanthoides spinosus, Ogygopsis klotzi, Oryctocephalus reynoldsi, Bathyuriscus rotundatus, Bathyuriscus ornatus,* and other species of the *Ogygopsis klotzi* fauna of Mount Stephen.

The specific name is given in recognition of Sir James Hector, the Canadian geologist and explorer who discovered the Hector or Kicking Horse Pass in 1858.

FORMATION AND LOCALITY.—Middle Cambrian: Ogygopsis shale of the Stephen formation, 2,400 feet (731.5 m.) above the Lower

[1] Moberg, 1903, Meddelande från Lunds Geol. Mineral. Inst. No. 5 (Geol. Fören. i Stockholm Förhandlingar, Bd. xxv, Häft 2, 1903, No. 219), pl. IV, figs. 1 and 2.

Cambrian and 2,600 feet (792.5 m.) below the Upper Cambrian; northwest slope of Mount Stephen, 3,000 feet (914.4 m.) above the Kicking Horse River, above Field, on the Canadian Pacific Railway, British Columbia, Canada.

Order OPISTHOPARIA Beecher

Family PARADOXIDÆ

ALBERTELLA, new genus

Dorsal shield elongate-ovate. Cephalon large, semicircular in outline, about one-fourth the length of the dorsal shield; genal angles extended into spines; cranidium subquadrangular in outline, with long palpebral lobes and narrow fixed cheeks; palpebral lobes elongate, with outer rims continued across the fixed cheeks as narrow ocular ridges; glabella subquadrilateral in outline, with short lateral furrows; strong occipital ring. The facial sutures cut the posterior border within the genal angles and pass inward and slightly forward to the base of the eyes, thence about the palpebral lobe, and forward with slight curvature to the front margin.

Thorax with seven segments; pleuræ terminating in short spines, those of the third or fourth segment in longer spines; pleural furrow with broad inner end largely filled in by an elongated tubercle.

Pygidium large, with central axis divided into several rings, and with the first, or first and second combined, anterior, anchylosed segments extended across the border into a long spine on each side.

GENOTYPE.—*Albertella helena,* new species.

STRATIGRAPHIC RANGE.—Upper beds of Lower Cambrian.

GEOGRAPHIC DISTRIBUTION.—Western Alberta, near the line of the Canadian Pacific Railway, Canada, and northern Montana, in the Lewis and Clark Forest Reserve.

OBSERVATIONS.—*Albertella* is a most interesting type of the order Opisthoparia and family Paradoxidæ. It should first be compared with the genus *Zacanthoides* Walcott,[1] which, in the British Columbia section, is first met with in strata 2,000 feet above the beds in which *Albertella* occurs. The cephalons of the two genera are generically the same. The thoracic segments are of the same type, but the third or fourth segment of the thorax of *Albertella* is extended into long pleural spines, and the thorax has seven instead of nine segments, as in *Zacanthoides*. The pygidium of *Albertella* has a long, strong spine extending from the pleural lobes of the first, or first and second combined, anterior segments, and a smooth border otherwise; the

[1] Walcott, 1888, American Jour. Sci., 3d ser., vol. XXXVI, p. 165.

pygidium of *Zacanthoides* has all the pleural segments extended as spines directly across the border.

The prominent differences between the two genera, then, are the extension in adult individuals of the third or fourth segment of the thorax in *Albertella,* and the presence on the pygidium of one pair of spines instead of many spines, as in *Zacanthoides.*

The extension of the third segment of the thorax occurs in the genera *Olenellus* Hall and *Mesonacis* Walcott,[1] and the spinose extension of the pleural elements of the pygidium occurs in *Parabolina* Salter,[2] *Hysterolenus* Moberg,[3] and other genera, but these other genera differ in so many other characters that it is unnecessary to make comparisons between them and *Albertella.*

ALBERTELLA HELENA, new species

PLATE 2, FIGURES 1–9

Dorsal shield of medium size; with the exception of spines, longitudinally elongate-ovate; moderately convex. Cephalon semicircular in outline, one-third the length of the dorsal shield; marginal border of medium width, slightly convex, delimited from the cheeks by a sharp, shallow furrow, and continued at the genal angles directly into long, slender spines that extend outward and backward to a line back of the union of the thorax and pygidium; posterior border narrow at the inner end next to the dorsal furrow, a little wider at the facial sutures, and arching a little forward before merging into the outer border at the genal spine; the posterior border is delimited from the cheeks by a narrow, shallow furrow that begins opposite the center of the occipital segment, and, arching forward a very little, passes into the furrow within the outer border. Cranidium convex, subquadrangular in outline exclusive of the extension of its postero-lateral limbs; the latter are of medium width, with nearly one-half of their area occupied by the posterior furrow and border. Fixed cheeks at the palpebral lobe one-third the width of the glabella; posteriorly they merge into the postero-lateral limbs; anteriorly they pass directly forward to the interborder furrow; palpebral lobe narrow, elongate, about three-fifths the length of the cephalon,

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[1] Walcott, 1891, Tenth Ann. Rept. U. S. Geol. Survey, pls. LXXXII, LXXXIII, LXXXIV, LXXXV, and LXXXVII.

[2] Moberg and Möller, 1898, Meddelande från Lunds Geol. Fältklubb, No. 3 (Geol. Fören. i Stockholm Förhandlingar, Bd. XX, Häft 5, 1898, No. 187), pls. XII and XIII.

[3] Moberg, 1898, Meddelande från Lunds Geol. Fältklubb, No. 5 (Geol. Fören. i Stockholm Förhandlingar, Bd. XX, Häft 6, 1898, No. 188), pl. XVII, figs. 1–9.

bordered by a narrow, rounded rim that is continued obliquely inward and forward, as an ocular ridge, across the fixed cheek to the dorsal furrow opposite the anterior pair of glabellar furrows. Glabella, including occipital ring, subquadrilateral, with sides slightly curved inward and front broadly rounded, moderately convex; the average sized glabella is marked by a pair of short, shallow furrows that extend obliquely inward and backward about one-third the distance across the glabella, and a pair of nearly transverse, short furrows that divide it into a short lobe on each side and a large anterior frontal lobe; the latter has a short, shallow furrow on each side about midway of its length that extends directly inward toward the central third of the width of the glabella; the glabella of a crandidium 23 mm. in length has a pair of deep, oblique, posterior furrows, and, in advance of them, four pairs of faint, short, nearly transverse furrows, the posterior pair of which are between the strong, oblique, posterior furrows and the longitudinal, median third of the glabella; a small dorsal shield with a cephalon 1.3 mm. in length, shows the oblique, posterior glabellar furrow and two pairs of the anterior furrows; occipital furrow strong, sharply defined, and curving forward at its ends; occipital ring strong, rounded, arching slightly backward with its antero-lateral angle extending forward. Free cheeks slightly convex, with the body rising from the inter-border furrow to the base of the elongate, low eye lobe. The facial sutures cut the posterior margin within the middle third of the distance from the dorsal furrow to the outer margin; they curve gently outward and then inward across the border, and thence with a slight sigmoid curve to the base of the eye lobe; arching over the latter, they extend forward with a slight outward arching to and across the frontal border, so as to cut the frontal margin within a longitudinal line drawn forward from the outer margin of the palpebral lobe.

Thorax with seven nearly transverse segments; axial lobe convex and arching slightly backward; a small, low node occurs at the center near the posterior margin, and a transverse, rounded, low ridge at each end next to the dorsal furrow; the pleura is nearly straight, somewhat flattened, and terminated by a sharp spine that extends obliquely outward and backward a short distance, except on the third segment, which has a strong spine extending backward nearly to a line opposite the posterior third of the pygidium; pleural furrow broad at the dorsal furrow and narrowing to its end at the base of the terminal spine; a rounded, elongate, subtriangular tubercle occupies its inner half; the anterior border of the pleura next to the dorsal furrow is a narrow, rounded ridge, which

widens gradually and passes directly into the terminal spine; the posterior border is a narrow, rounded ridge that merges into the base of the terminal spine.

Pygidium moderately convex, about one-fourth of the length of the dorsal shield, elongate, semicircular in outline; axial lobe convex, divided by five shallow, narrow, transverse furrows into five rings and a terminal section that is within the border; pleural lobes marked by the pleural furrows of four anchylosed segments that merge into the smooth border; a slender but strong, long spine extends from a strong base on each side of the pygidium; this spine appears to be the extension of the anterior anchylosed segment.

Surface finely granulose, with scattered larger granules on small specimens.

DIMENSIONS.—A dorsal shield 40 mm. in length has the following dimensions:

	mm.
Cephalon:	
Length	13.5
Width at posterior margin	31.5
Thorax:	
Length	17.0
Width at first segment	22.0
Pygidium:	
Length	9.5
Width	15.0

OBSERVATIONS.—A dorsal shield 2.7 mm. in length, with a cephalon 2.3 mm. long, has a fixed cheek nearly as wide as the glabella, an eye lobe fully one-half the length of the cephalon, and the glabella slightly expanded toward the front. A large cranidium, 23 mm. in length, has a glabella proportionally wider in front, and very strong, posterior, oblique furrows.

This species was first found in 1904, on Gordon Creek, Ovando Quadrangle, Montana, in argillaceous shales, a short distance above the supposed Flathead sandstones, in association with

Acrothele colleni, new species,
Wimanella simplex, new genus and new species,
Olenopsis,
Ptychoparia, and
Bathyuriscus, sp. a.

The stratigraphic position of this subfauna was not determined in Montana, owing to the break in the continuity of the section on Gordon Mountain.

The specific name is given in recognition of the discovery by Mrs.

Walcott, in 1907, of this species and the accompanying subfauna on Mount Bosworth, in the Canadian Rockies. Its position was determined to be at the summit of the Lower Cambrian portion of the section, 2,450 feet below the *Ogygopsis klotzi* fauna of Mount Stephen.

The subfauna at the Mount Bosworth locality includes

Micromitra (*Iphidella*) *wapta*, new species,
Obolus parvus, new species,
Acrothele colleni, new species,
Wimanella simplex, new genus and new species,
Albertella bosworthi, new species.
Albertella helena, new species, and
Bathyuriscus, sp. a.

Formation and Locality.—Lower Cambrian: (1) Drift block of siliceous shale on the south slope of Mount Bosworth, on the "Continental Divide," one mile east of Hector, on the Canadian Pacific Railway, British Columbia, Canada; and (2) Wolsey argillaceous shale, on Gordon Creek, 4 miles (2.5 km.) above its union with Danaher Creek, at the southeast foot of Gordon Mountain, Lewis and Clark Forest Reserve, Montana, U. S. A.

ALBERTELLA BOSWORTHI, new species

Plate 1, Figures 4–7

This species differs from the associated *Albertella helena* in its cephalon, thorax, and pygidium. In the cephalon the eye and palpebral lobe are more elongate and nearer proportionally to the outer margin. In the thorax the pleuræ of the fourth segment are extended into long spines instead of those of the third, as in *A. helena;* the pleural lobes and the entire thorax are narrower in proportion to the length. In the pygidium there are six rings in the axis instead of three or four, and two anchylosed pleural segments pass into the large lateral spines instead of one. Both species have seven thoracic segments and a finely granulated surface and are associated in the same layers of shale at the Mount Bosworth locality.

Formation and Locality.—Lower Cambrian: Drift block of siliceous shale on south slope of Mount Bosworth, on the "Continental Divide;" one mile east of Hector, on the Canadian Pacific Railway, British Columbia, Canada.

Family OLENIDÆ Salter

ORYCTOCARA, new genus

Dorsal shield small, elliptical. Cephalon semicircular in outline, from one-third to one-fourth the length of the dorsal shield; genal angles and free cheeks unknown; cranidium subquadrangular in outline exclusive of the narrow postero-lateral limbs; glabella subquadrangular in outline, with three lobes and an occipital ring; the lobes are separated by very slightly defined, transverse furrows terminating in round pits within the lateral margin of the glabella. The facial sutures cut the posterior margin of the head within the genal angles and pass inward and slightly forward to the base of the eye and thence about the palpebral lobe and forward with a slightly outward curvature to the frontal rim. Fixed cheeks broad. Eyes long, with the margin of the palpebral lobe extending across the fixed cheeks as an ocular ridge.

Thorax with eleven segments; pleuræ with straight furrows and abrupt, truncated ends.

Pygidium large, with central axis divided into several rings by transverse furrows, all of which extend across the pleural lobes to the outer margin.

GENOTYPE.—*Oryctocara geikiei,* new species.

OBSERVATIONS.—The cranidium of this genus is much like that of *Oryctocephalus* Walcott,[1] but the thorax and pygidium are unlike. The pleuræ are of the *Olenus* Salter type in having a straight median furrow, while the pygidium is broad and of the *Bathyuriscus*[2] type. (See pl. 1, fig. 2, of this paper.)

The genus is referred to the order Opisthoparia Beecher and to the family Olenidæ Salter.

Only one species from the central portion of the Middle Cambrian is now known.

ORYCTOCARA GEIKIEI, new species

PLATE 1, FIGURES 9, 10

Dorsal shield small, longitudinally elliptical in outline, moderately convex. Cephalon semicircular in outline, a little less than one-third the length of the dorsal shield; free cheeks and genal angles unknown; a narrow, rounded rim extends across the front of the cranidium and it is probable that it continued along the free cheeks and terminated in a small genal spine. Cranidium subquadrangular

[1] Walcott, 1886, Bull. U. S. Geol. Survey, No. 30, p. 210.

[2] Meek, 1873, Sixth Ann. Rept. U. S. Geol. Survey Territories for 1872, p. 484.

in outline exclusive of the postero-lateral limbs; the latter are elongate, subtriangular in outline, and with a narrow, transverse furrow within a rounded rim of medium width. Fixed cheek about two-thirds the width of the glabella and merging posteriorly into the postero-lateral limb and anteriorly extending to the frontal rim; there is no defined frontal limb, owing to the glabella extending to the furrow within the frontal rim; palpebral lobe narrow, rounded, about one-half the length of the cranidium, and with its outer rim extending across the fixed cheek as a narrow ocular ridge nearly parallel to the frontal rim of the cranidium; the palpebral lobe terminates a short distance back of the frontal margin of the glabella. Glabella subquadrangular; slightly narrower at the broadly rounded front than at the occipital ring, moderately convex; divided by four faint, transverse furrows into three transverse lobes, an anterior, terminal lobe and an occipital ring; the faint, transverse furrows terminate on each side in round pits a short distance from and within the margin; occipital ring narrow and rounded. Free cheeks unknown. The facial sutures cut the posterior margin on each side a short distance from the genal angle and extend inward and slightly forward to the base of the eyes; curving over the eyes they extend forward with a slight outward direction, so as to cut the front margin on a line with the outer edge of the palpebral lobe.

Thorax with eleven nearly transverse segments; the axial lobe is convex and one-half the width of the pleural lobes; the segments of the axial lobe have a deep transverse furrow with the margins elevated; the doublure on the front margin of each segment curves downward, so as to pass beneath the downward slope of the posterior half of the next segment in advance of it; the extremity of each segment curves slightly forward, so that the furrow passes out upon the pleura a little in advance of its position at the center of the axial lobe and in front of the pleural furrow; the pleura is straight, nearly flat, and terminating in a blunt, straight margin without spine or backward curvature; the most careful examination fails to reveal spine or falcate extremity; the entire side of the thorax appears as though a sharp knife had cut off the ends of all the pleura from the cephalon to the pygidium; the pleural furrows of each segment originate on a low swelling between the axial and pleural lobes of each segment and extend directly outward to nearly the end of the segment, where they fade away, so as to leave the end of the segment flat; the pleural furrows are about one-third of the width of the segment and arch forward a very little between its two extremities.

Pygidium large, moderately convex; anterior margin slightly arched, so as to join with the posterior segment of the thorax; posterior outline semicircular; axial lobe convex and about two-thirds the length of the pygidium; it is divided into seven transverse rings and a terminal section by transverse furrows; the pleural lobes slope gently from the axial lobe to the lateral and posterior margins; their entire surface is marked by the anchylosed segments, which are similar in appearance to the thoracic segments, except that their backward curvature increases until the pleuræ of the posterior segments are nearly parallel to the axis of the pygidium; the furrows and narrow ridges from the terminal segment of the axis extend backward with a slight inward curvature; all furrows and ridges terminate just within the outer margin in the same manner as those of the thoracic pleura.

Surface with relatively large granules on all parts of the dorsal shield.

Dimensions.—A dorsal shield 7.25 mm. in length has the following dimensions:

	mm.
Cephalon:	
Length	1.75
Length of glabella	1.50
Width	2.50
Width of glabella	1.00
Thorax:	
Length	3.75
Width	4.00
Width of axial lobe at sixth segment	8.00
Width of pleural lobe	1.60
Pygidium:	
Length	1.75
Width at anterior margin	3.50

Observations.—This is a very rare species, as only one nearly entire specimen is known; this has the pygidium displaced and the free cheeks are missing. The combination of characters found in several genera is shown (*a*) in the cranidium, in which the glabella is like that of *Oryctocephalus* Walcott; (*b*) in the thorax, which is not unlike that of *Olenus* Salter; and (*c*) in the pygidium, which suggests in relative size and form the pygidium of *Bathyuriscus howelli* Walcott.[1] Among the associated fossils are *Micromitra (Iphidella) pannula* (White), *Ptychoparia piochensis* Walcott, *Ptychoparia cordilleræ* (Rominger), *Oryctocephalus reynoldsi* Reed, *Zacanthoides idahoensis,* new species, and *Bathyuriscus howelli* Walcott.

[1] Walcott, 1886, Bull. U. S. Geol. Survey, No. 30, p. 216.

FORMATION AND LOCALITY.—Middle Cambrian: Spence shale of the Ute formation, 2,755 feet (839.7 m.) below the Upper Cambrian in the Liberty Canyon section; Spence Gulch, a ravine running up into Danish Flat from Mill Canyon, about 15 miles (9.37 km.) west of Montpelier and 5 miles (3.12 km.) west-southwest of Liberty, Bear Lake County, Idaho, U. S. A.

Genus ZACANTHOIDES Walcott

ZACANTHOIDES IDAHOENSIS, new species

PLATE 3, FIGURES 1–11

Dorsal shield large for a species of this genus, moderately convex, longitudinally elliptical in outline. Cephalon semicircular in outline, one-third the length of the adult dorsal shield; bordered by a rounded rim of medium width that is continued into strong, sharp genal spines that extend backward about one-half the length of the thorax; the posterior border is narrow next to the glabella, from where it widens out to the intergenal spine within the line of the facial suture; beyond the facial suture it curves forward and merges into the lateral border at the base of the genal spine; the posterior intermarginal furrow is sharply defined, and occupies most of the space between the border and the facial suture; on the sides and front of the cephalon the intermarginal furrow is narrow and distinct. Cranidium with a large glabella, short, small antero-lateral limbs, and elongate, slender postero-lateral limbs that have a short, sharp, slender, intergenal spine extending outward and backward from the outer posterior margin; fixed cheeks scarcely more than the inner sides of the large palpebral lobes and a small, subtriangular area in front of the latter; postero-lateral limbs formed of the marginal border and strong, intermarginal furrows; a narrow frontal limb extends across between the glabella and the interborder furrow; palpebral lobe about three-fifths the length of the cranidium and bordered by a narrow, rounded rim that begins, posteriorly, near the median axis opposite the occipital ring, and, curving outward, forward, and then inward, terminates at the dorsal furrow beside the glabella; it is separated from the body of the lobe by a rounded, shallow furrow. Glabella elongate, subquadrilateral in outline, moderately convex in front, sides nearly straight, broadly rounded, and separated from the fixed cheeks and palpebral lobes by a narrow, distinct furrow; surface marked by a pair of posterior furrows that extend obliquely inward, so as to outline two small subtriangular lobes, and two pairs of short, more transverse furrows; the anterior pair is nearly opposite the anterior end of the

palpebral lobe, and the second pair about half way between them and the outer ends of the posterior pair; on some specimens a fourth pair is faintly defined on the large anterior lobe close to the dorsal furrow opposite the rounded angle formed by the sides and rounded front of the glabella. Occipital ring strong, rounded, broadest at the center, and narrowing gradually toward the ends; marked by a small central node near the posterior margin and a rounded, small, depressed tubercle at about one-half the distance between the central node and the dorsal furrow; occipital furrow distinct, narrow, and nearly transverse. Free cheeks large, body gently convex, and rising from the interborder furrow to the base of the elongate, low eye lobe. The facial sutures cut the posterior margin just outside of the intergenal spine and, curving abruptly inward, extend to the posterior base of the eye lobe; arching over the latter, they extend forward and slightly outward with a gentle sigmoid curve, so as to cut the outer margin at a distance from the median line of the cranidium equal to the width of the glabella.

Thorax with nine segments; axial lobe convex, a little wider than the pleural lobes exclusive of the spinose terminations of the pleuræ; a small elongate node occurs at the center on the posterior half of each segment, except on the fifth, which has a long, slender, backward-extending spine; on each side, about half way between the center and the dorsal furrow and nearest the anterior margin, there is a rounded, low tubercle, and on the more perfectly preserved specimens a low, rounded, transverse ridge on each side next to the dorsal furrow; pleural lobes slightly convex; each pleura has a strong furrow that is broad at the inner end next to the dorsal furrow, from whence it narrows gradually to its sharp extremity near the posterior outer end of the pleura just within the base of the terminal spine; a rounded, elongate, subtriangular tubercle occupies much of the broad inner end of the furrow; the front border of each pleura is narrow next to the dorsal furrow; it gradually widens toward the outer end and terminates in a strong, long, backward-extending spine; the narrow posterior border merges into the base of the terminal spine; in most specimens the backward curvature of the anterior margin of the pleura is so abrupt that an obtuse angle is formed, while in some the margin curves gradually into the terminal spine.

Pygidium of medium size; axial lobe convex, narrow, broader than the pleural lobes, divided by narrow, transverse furrows into four rings and a terminal section that, in large specimens, has a slight, transverse furrow that delimits a fifth narrow ring; on the

pleural lobes four anchylosed segments are outlined by narrow, deep furrows; only the two anterior preserve any trace of the pleural furrow, and these are very short and obscure; the pleural segments are mainly made up of the thickened, broad, anterior border and the strong, backward-extending, rounded spines; the outer border is usually obscured until after the fourth spine is passed, and even then in some specimens the short fifth and sixth pairs of spines obscure it; on other specimens the posterior spines are so slightly developed that the outline of the border is preserved.

Surface finely granular.

DIMENSIONS.—A dorsal shield 38 mm. in length has the following dimensions:

	mm.
Cephalon:	
Length	13.0
Width at base	30.0
Length of eye lobe	7.0
Length of glabella	10.0
Width of glabella, base	6.0
Width of glabella, front	6.5
Thorax:	
Length	17.5
Width	21.0
Axial lobe, anterior segment	8.0
Axial lobe, posterior segment	4.5
Pleural lobe, anterior segment	6.5
Pleural lobe, posterior segment	3.0
Pygidium:	
Length	7.5
Width	10.0
Axial lobe, anterior segment	4.5
Axial lobe, posterior segment	2.5

The preceding description is based on adult specimens averaging 38 to 45 mm. in length. A large number of young and small specimens were found in association with the larger adults, some of which exhibit stages of growth. A specimen 1.9 mm. in length (fig. 5) preserves the cranidium and five segments of the thorax. The glabella widens out toward the front, and the occipital furrow is very faint; the base of the palpebral lobe is farther out on the posterior margin than in the adult, and its anterior end is at the dorsal furrow and nearer the antero-lateral, rounded angle of the glabella. The pleural lobe has somewhat broader, more direct furrows on the pleura, and the spine of the fifth segment is very large; another important character is the greater extension of the terminal spines of the third thoracic segment—a character unknown in the

later stages of growth of this species and a character persistent in *Albertella helena,* which occurs over 2,000 feet (609.6 m.) lower than the horizon of *Zacanthoides spinosus* (Rominger) in the Cambrian section of the Canadian Rocky Mountains. It also occurs in the adult forms of *Mesonacis vermontana*[1] and other trilobites of the *Olenellus* fauna. A specimen of the entire dorsal shield 3.2 mm. in length has the same widening of the glabella toward the front as the smaller specimen, but the base of the palpebral lobes have drawn in toward the glabella, and the glabella has extended forward beyond the anterior extremities of the palpebral lobes; the thorax has only adult characters, except that the third segment appears to have on one side a stronger terminal spine, and there are but seven segments; the spines on the border of the pygidium are short, and but four can be seen on each side. Specimens 8 mm. in length have all adult characters in the cephalon and thorax, with the exception of the terminal spines of the pygidium, which are shorter and less clearly defined at the crossing of the border.

OBSERVATIONS.—This species occurs abundantly in Idaho. When collecting it I thought it to be *Zacanthoides typicalis,*[2] but on direct comparison with that species it was found to differ in having the posterior end of the palpebral lobe nearer the glabella; the glabella proportionally narrower in front, and larger antero-lateral parts of the fixed cheek; a broader thoracic axis in proportion to the pleural lobes; a long median spine on the fifth instead of seventh segment; a larger pygidium, with broader pleural lobes, more rings on the axis, and more terminal spines on the pygidium. It is found to differ from *Zacanthoides spinosus* (Walcott)[3] in having the glabella less expanded toward the front; palpebral lobes nearer the glabella at their posterior end; smaller antero-lateral parts of the fixed cheek; absence of a strong occipital spine; in the thorax it differs in having a long median spine on the central axis at the fifth segment instead of the seventh, and the axial lobe is proportionally wider; the pygidium differs in having four rings on the axis instead of three; the axial lobe is proportionally longer, and the spines on the pygidium differ in details of shape and number. The three species occur at the same relative geological horizon, but are widely separated. *Z. typicalis* occurs at Pioche, Nevada, 350 miles south-southwest of the locality of *Z. idahoensis* at Spence Gulch, 15 miles

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[1] Walcott, 1891, Tenth Ann. Rept. U. S. Geol. Survey, pl. LXXXVII, fig. *1a;* see also pls. LXXXIV and LXXXV.

[2] Walcott, 1886, Bull. U. S. Geol. Survey, No. 30, p. 183.

[3] Walcott, Mon. U. S. Geol. Survey, vol. VIII, 1884, p. 63; and Bull. U. S. Geol. Survey, No. 30, 1886, p. 184.

west of Montpelier, Idaho; *Z. spinosus* is from Mount Stephen, in British Columbia, 685 miles north-northwest of Spence Gulch. Among the associated fossils are *Bathyuriscus howelli* Walcott, *Oryctocephalus reynoldsi* Reed, *Oryctocara geikiei* Walcott, *Micromitra (Iphidella) pannula* (White).

FORMATION AND LOCALITY.—Middle Cambrian: Spence shale of the Ute formation, 2,755 feet (839.7 m.) below the Upper Cambrian in the Liberty Canyon section; Spence Gulch, a ravine running up into Danish Flat from Mill Canyon, about 15 miles (9.37 km.) west of Montpelier, and 5 miles (3.12 km.) west-southwest of Liberty, Bear Lake County, Idaho, U. S. A.

Genus NEOLENUS Matthew

NEOLENUS INFLATUS, new species

PLATE 5, FIGURES 1–5

Dorsal shield large, elongate-elliptical in outline; axial lobe strongly convex. Cephalon semicircular in outline, with the genal angles produced into sharp spines about one-half the length of the cephalon; a narrow, rounded rim extends across the front of the cranidium, and, widening a little, runs along the outer margins of the free cheeks to the genal angles. The facial sutures cut the posterior margin well within the genal angles with an outward direction to the posterior furrow, where they curve inward and forward to the base of the eye lobe; arching over the eye lobes they curve outward to about the line of the outer rim of the palpebral lobe, forward to the frontal rim, and then obliquely inward across the rim to the front margin. Cranidium with a prominent, tumid glabella, narrow fixed cheeks, small antero-lateral limbs, and strong postero-lateral limbs. Glabella large, convex; the frontal lobe is inflated and, in all but young, small specimens, overhangs the frontal rim; the sides gradually expand from the occipital ring to the broadly rounded front, which extends forward to, and lies parallel with, the furrow within the rounded frontal rim; the anterior half of the glabella is taken up by the expanded, anterior lobe and the posterior half is divided into four narrow lobes by shallow furrows that extend obliquely inward and slightly backward nearly to the median line; in some specimens, especially the young, the furrows are very faintly defined; occipital ring separated from the glabella by a narrow, shallow furrow; it is broad, moderately convex, and with a strong, long, sharp, arching spine that extends back over the thorax nearly to the pygidium; the base of the spine occupies nearly the entire width of the occipital ring at its center. Fixed cheeks

about one-fourth the width of the glabella, gently convex and merging into the anterior and posterior limbs; the posterior limb is about twice as long as deep below the eye lobe and marked by a strong furrow within the broad, slightly convex posterior border; palpebral lobe small, 7 mm. long in a cephalon having a length of 35 mm. at the eye lobes; it is bordered by a rounded rim that continues obliquely forward across the fixed cheek and merges into the side of the glabella. Free cheeks large, gently convex; bordered by a rounded rim that is continued posteriorly into a spine; posterior margin rather broad and about one-third the length of the margin between the genal angles and the occipital ring; eye lobe small and not high. The genal spine is situated some distance out from the central axis, so that it clears the terminal spines of the thoracic pleuræ.

Thorax with seven nearly transverse segments; axial lobe convex, with the segments slightly rounded and a small node at the center of each; a low, narrow, transverse ridge occurs on each side near the union of the axial and pleural lobes; pleural lobes a little wider than the axial lobe and slightly convex; the pleura is straight, out to the backward curving, terminal spine; the narrow pleural furrow originates at the inner end next to the axis and passes obliquely outward, terminating just back of the center of the pleura at the base of the terminal spine; the latter has a strong base and narrows rapidly to a sharp point as it extends outward and backward a short distance.

Pygidium large, moderately convex; anterior margin nearly transverse, posterior outline broadly semi-elliptical; axial lobe convex and narrowing gradually from the anterior margin to the terminal ring at the narrow posterior border; it is divided into ten strong, rounded, transverse rings and a terminal section by ten narrow furrows; the terminal section in large specimens has a transverse pit on each side of its center that indicates an eleventh ring; a low node is indicated at the center of each ring, and a low, narrow, transverse swelling occurs near the dorsal furrow on each side; in a pygidium 8 mm. in length there are nine clearly defined, axial rings, a faint, tenth ring, and an elongate, rounded, terminal section; pleural lobes slightly convex out to the spinose border, which is flattened between the termination of the pleural grooves and its outer edge; the eight marginal spines on each side are similar to those of the pleural lobes of the thorax with the exception of the posterior ones, which extend directly backward; the space between the axial lobe and the margin is marked by the pleural furrows and the narrow

furrows indicating seven anchylosed segments; the posterior furrows are nearly parallel to the sides of the axial lobe; the furrows all terminate on the inner portion of the outer border, the pleural furrows with a slight, elongate pit just within the border.

Surface with variously arranged, irregular, raised lines or narrow, sharp ridges; on the glabella they are very slender and arranged in a somewhat concentric manner, although they are broken and irregular; on the fixed and free cheeks the raised lines are much stronger, irregular, and more or less anastomosing; on the thoracic segments the short, irregular raised lines cross the segments of the axis on each side between the central node and the dorsal furrow, and on the pleuræ they extend obliquely across the raised spaces between the furrows; the pygidium has about the same markings at the thorax except on the flattened border, where the short, elevated, irregular lines extend across the border.

Dimensions.—There are two small, nearly entire dorsal shields. One, having a length of 24 mm. exclusive of the posterior spines of the pygidium, has the following dimensions:

	mm.
Cephalon:	
Length	9.5
Width at posterior margin	11.5
Thorax:	
Length	8.0
Width at first segment	14.0
Pygidium:	
Length	7.5
Width at anterior margin	10.0

A large cranidium, 52 mm. in length, has the following dimensions:

	mm.
Glabella:	
Length	42.0
Width at posterior margin	88.0
Width at occipital furrow	26.0
Width just in front of ocular ridge	34.0
Palpebral rim, length	7.0

A large pygidium, 58 mm. in length, has the following dimensions:

	mm.
Width at anterior margin	76.0
Axial lobe, length	52.0
Axial lobe, width at anterior margin	19.0
Axial lobe, width at anterior segment	19.0
Axial lobe, width at posterior section	10.0
Pleural lobe, width at anterior margin	28.5

Hypostoma strongly convex, elongate, strongly rounded at the base, narrowing toward the broadly rounded posterior margin; border slightly flattened, with a rounded edge; this edge is arched slightly upward on the sides at about the posterior third of the length of the hypostoma; a shallow furrow crosses the posterior end of the convex body a short distance in front of the posterior margin and subparallel to it; the alate lateral limbs are subtriangular in outline and slightly convex. The surface is marked by fine, irregular, elevated lines that are subparallel to the rim on the margin and roughly concentric on the body. An hypostoma 26 mm. in length has a width of 28 mm. at its base, 15 mm. at the arches in the margin or at the posterior third; convexity at center, 5 mm.

The above-described hypostoma is associated with this species, *Neolenus superbus,* and a less convex hypostoma which is referred to the latter species.

Observations.—This large species and the associated *Neolenus superbus* appear to mark the extreme development in size of species of *Neolenus* and its latest occurrence in Cambrian time. Fragments of both species are abundant at one locality, and a few entire specimens have been found. It is the largest of the Cordilleran Cambrian trilobites, some of the partially entire specimens indicating a length of 160 mm., width 83 mm.

The most nearly related species is *Neolenus superbus,* from which *Neolenus inflatus* differs in having an inflated glabella, a longer pygidium, and in minor details of the pleuræ of the thoracic segments, pygidium, and cephalon. The inflated glabella, long pygidium with ten rings and spinose terminations of the thoracic pleuræ, separate it from *Neolenus serratus* (Rominger),[1] the type of the genus. The latter also has a granular surface and falcate terminations to the pleuræ of the thoracic segments, and the faunal horizon of *N. serratus* is 1,900 to 2,125 feet below that of *N. inflatus.*

Formation and Locality.—Middle Cambrian: 1,895–2,140 feet (605–653.8 m.) below the Upper Cambrian and about 2,000 feet (609.6 m.) above the beds containing *Zacanthoides typicalis* Walcott and *Bathyuriscus howelli* Walcott, the horizon which is correlated with the horizon carrying *Neolenus serratus* (Rominger) in British Columbia,[2] in thin-bedded limestones of the Marjum formation, in ridge on east side of Wheeler Amphitheater, east of Antelope Springs, House Range, Millard County, Utah, U. S. A.

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[1] *Ogygia serrata* Rominger, 1887, Proc. Acad. Nat. Sci. Philadelphia, p. 13.

[2] This British Columbia horizon is given in detail in the Formation and locality of *Burlingia hectori.*

NEOLENUS INTERMEDIUS, new species

PLATE 6, FIGURES 1–7

This species, as its name implies, is an intermediate form between *N. superbus* and *N. inflatus.* It differs from both of those species in the absence of an occipital spine; and in having the sides of the glabella more nearly parallel and with the glabella less expanded in front, and somewhat more pointed or less abruptly rounded. The pleural lobes of the thorax have a terminal spine on the pleuræ extending backward somewhat more abruptly than in either of the other species.

The pygidium has five or six rings in the axial lobe and a terminal segment. *N. inflatus* has ten or eleven rings in the axial lobe and *N. superbus* has eight rings; *N. intermedius* has the same number of terminal spines as *N. superbus,* but the spines are curved backward much more than in the latter species.

As far as known, this species does not attain the size of either *N. superbus* or *N. inflatus.* The largest cephalon in the collection has a length of 35 mm. The proportions of the head and pygidium are about the same as *N. superbus.* The hypostoma referred to this species is proportionally broader and with a larger body proportionally than that of *N. inflatus* or *N. superbus.* In other respects it is very much like the hypostoma of *N. superbus.*

DIMENSIONS.—A dorsal shield 74 mm. in length has the following dimensions:

	mm.
Cephalon:	
Length	26.5
Length of glabella	21.0
Length of eye lobe	4.4
Width at posterior margin	44.0
Width of glabella at posterior margin	13.5
Width of glabella at anterior end	15.0
Thorax:	
Length	27.0
Width	41.0
Width of axial lobe at first segment	13.0
Width of pleural lobe at first segment	13.5
Pygidium:	
Length	20.5
Width	35.0
Width of axial lobe at anterior ring	10.0
Width of axial lobe at posterior ring	7.5

The surface markings of this species are much like those of *N. superbus* and *N. inflatus,* but very much finer. On a cranidium 11 mm. in length the surface appears smooth, except under a strong lens.

FORMATION AND LOCALITY.—Middle Cambrian: 1,895–2,140 feet (605–653.8 m.) below the Upper Cambrian and about 2,000 feet (609.6 m.) above the beds containing *Zacanthoides typicalis* Walcott and *Bathyuriscus howelli* Walcott, the horizon which is correlated with the horizon carrying *Neolenus serratus* (Rominger) in British Columbia,[1] in thin-bedded limestones of the Marjum formation, in ridge on east side of Wheeler Amphitheater, east of Antelope Springs, House Range, Millard County, Utah, U. S. A.

NEOLENUS INTERMEDIUS PUGIO, new variety

PLATE 6, FIGURES 8, 9

This variety is founded on four specimens of a pygidium that has four rings and a terminal segment in the axial lobe, four marginal spines on each side and three clearly defined anchylosed pleural segments marked by oblique pleural furrows. A specimen 11 mm. in length has a width at the front of 36 mm. The axial lobe has a width of 5 mm. at the first segment and 3 mm. at the terminal segment.

This variety differs from *N. intermedius* in having four instead of five marginal spines on each side of the pygidium, four axial rings instead of five and a shorter terminal section to the axial lobe. A fragment of the outer surface shows it to have been of the same type as that of *N. superbus.*

FORMATION AND LOCALITY.—Middle Cambrian: 1,895–2,140 feet (605–653.8 m.) below the Upper Cambrian and about 2,000 feet (609.6 m.) above the beds containing *Zacanthoides typicalis* Walcott and *Bathyuriscus howelli* Walcott, the horizon which is correlated with the horizon carrying *Neolenus serratus* (Rominger) in British Columbia,[1] in thin-bedded limestones of the Marjum formation, in ridge on east side of Wheeler Amphitheater, east of Antelope Springs, House Range, Millard County, Utah, U. S. A.

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[1] This British Columbia horizon is given in detail in the Formation and locality of *Burlingia hectori.*

NEOLENUS SUPERBUS, new species

PLATE 4, FIGURES 1-5

Dorsal shield large, longitudinally elliptical in outline, moderately convex. Cephalon subsemicircular in outline, one-third of the length of the dorsal shield; bordered by a strong, slightly convex outer margin that is continued at the genal angles into strong, sharp spines that extend backward and slightly outward to about opposite the fourth thoracic segment; the posterior marginal border is narrow next to the glabella, from where it gradually broadens to the base of the genal spine; between the facial suture and the genal spine the margin arches abruptly forward, so as to throw the base of the genal spine in front of the line of the posterior margin; a well defined but narrow furrow separates it from the fixed cheek. Cranidium with a large glabella, narrow antero-lateral limbs, and large postero-lateral limbs; fixed cheeks narrow opposite the palpebral lobes; anteriorly they extend as a narrow, short section to the front border, and posteriorly merge into the postero-lateral limb, which is nearly as deep from the eye lobe to the posterior margin as from the glabella to its postero-lateral angle; palpebral lobe narrow, short, and with its outer rim extended diagonally from and across the fixed cheek to the dorsal furrow, next to the glabella.

Glabella elongate, moderately convex; sides nearly straight, and separated from the fixed cheeks by a narrow, strong furrow, slightly wider where the sides touch the frontal border than at the occipital furrow; front broadly rounded and subparallel to the anterior margin of the cranidium; surface marked by three pairs of short, oblique furrows that extend inward and slightly backward about one-third the distance across the glabella; a small pit occurs in the dorsal furrow at the antero-lateral angles, and from it a short, obscure furrow extends directly inward for a short distance; the glabellar furrows are not at all prominent. Occipital ring narrow at the ends, gradually becoming stronger and more convex toward the center, where a strong, backward arching spine has its base; occipital furrow nearly transverse, shallow, and terminating in advance of the furrows of the fixed cheeks. Free cheeks relatively small; the body rises with very little convexity from within the strong outer border to the base of the short, low eye lobe. The facial sutures cut the posterior margin a short distance within the genal spine, curve slightly outward across the border, and then inward with a gentle sigmoid curve to the base of the eye lobe; arching over the latter, they extend forward with a slight outward arching across the border, so as to cut the front margin on a line with the center of the eye lobe.

Thorax with seven segments; axial lobe convex, and as wide as the pleural lobes exclusive of the terminal spines; a strong, short, sharp spine occurs at the center of each segment, and a narrow, transverse, low, rounded ridge on each side next to the dorsal furrow; the pleural lobes are slightly convex; each pleura has a strong, diagonal furrow that originates near the front margin next to the dorsal furrow and gradually widens toward the outer end, where it terminates nearly at the center of the pleura and within the base of the sharp, terminal spine; a narrow, rounded ridge occurs on each side of the pleural furrow that forms the margins of the pleuræ; the terminal spines have a broad base and extend obliquely outward and slightly backward a short distance.

Pygidium large, moderately convex; anterior margin nearly transverse and posterior outline semicircular; axial lobe convex, a little shorter than the entire length; it is divided into seven rings and a terminal section by seven nearly transverse, narrow furrows; a low, narrow median ridge is indicated by the termination of the deeper portion of each transverse furrow just outside of the median line; five anchylosed pleural segments are outlined on the pleural lobes on each side of the axial lobe; the furrows all terminate within the slightly flattened, rounded border, which has five straight, narrow spines extending out from it on each side; the anterior segment of the pygidium is so much like the segments of the thorax that it is difficult to distinguish it from the thorax.

Hypostoma similar to that of *Neolenus inflatus,* except that its body is less convex, and small specimens show an elongate tubercle on each side just back of the line separating the convex body from its posterior, less convex, and narrower portion.

Surface with variously arranged, irregular, short, very fine, raised lines or minute ridges; on the glabella they are arranged in a concentric manner, although very irregular and interrupted by numerous breaks in continuity and strength; on the cheeks the lines are somewhat coarser; on the thorax and pygidium the lines are exceedingly fine and inconspicuous; where seen they have about the same arrangement as those of the surface of *Neolenus inflatus.*

DIMENSIONS.—A dorsal shield 65 mm. in length has the following dimensions:

	mm.
Cephalon:	
Length	23.00
Length of glabella	17.00
Length of eye lobe	2.75
Width at base	38.00
Width of glabella at posterior margin	12.00
Width of glabella at anterior end	13.50

Thorax:	mm.
Length	24.00
Width	30.00
Width of axial lobe at first segment	10.00
Width of pleural lobe at first segment	10.00
Pygidium:	
Length	18.00
Width	26.00
Width of axial lobe at anterior ring	9.00
Width of axial lobe at posterior ring	6.50
Hypostoma:	
Length	29.00
Length of body	26.00
Width	18.00
Width at base	23.00
Width at junction with head	33.00
Greatest width of body	19.00

OBSERVATIONS.—This species attains a large size. A cephalon and six thoracic segments has a length of 73 mm., a width of thorax of 70 mm.; with the seventh segment and the pygidium, exclusive of spines, the entire shield would have had a length of 107 mm. Fragments occur that indicate even a larger size.

Neolenus superbus and the associated *Neolenus inflatus* have many characters common to each; both attain a large size, both have small eyes, subquadrilateral glabellas, spinose genal angles, seven thoracic segments, spinose terminations to pleural segments and border of pygidium, occipital and thoracic median spines, lined surfaces, and resemble each other in minor details. The two species differ in the glabella of *N. superbus* being slightly convex with nearly parallel sides, instead of being inflated and expanded toward the front. The pygidium of *N. superbus* has seven axial rings and five spines on the border; that of *N. inflatus* has nine rings and eight spines. *Neolenus serratus* (Rominger)[1] has a broader dorsal shield, falcate terminations to the pleural segments, four rings on the axis of the pygidium, a subquadrangular glabella and genal spines that are formed by the union of the outer border and posterior border, instead of being a continuation of the outer border, as in *N. superbus* and *N. inflatus*. The surface of *N. serratus* is granular and not raised lines, as in *N. superbus*.

FORMATION AND LOCALITY.—Middle Cambrian: 1,895–2,140 feet (605–653.8 m.) below the Upper Cambrian and about 2,000 feet (609.6 m.) above the beds containing *Zacanthoides typicalis* Walcott and *Bathyuriscus howelli* Walcott, the horizon which is correlated

[1] *Ogygia serrata* Rominger, 1887, Proc. Acad. Nat. Sci. Philadelphia, p. 13.

with the horizon carrying *Neolenus serratus* (Rominger) in British Columbia,[1] in thin-bedded limestones of the Marjum formation, in ridge on east side of Wheeler Amphitheater, east of Antelope Springs, House Range, Millard County, Utah, U. S. A.

Genus BATHYURISCUS Meek

BATHYURISCUS ORNATUS, new species

PLATE 1, FIGURES 1–3

Dorsal shield small for the genus, longitudinally oval in outline, moderately convex. Cephalon semicircular in outline; a little less than one-third the length of the dorsal shield; bordered by a narrow, rounded margin that passes, at the rounded genal angle, into the very narrow posterior border; the interborder furrow is sharply defined all about the outer border, and within the posterior border it is a straight, rather broad, shallow furrow. Cranidium large, with very small antero-lateral and large postero-lateral limbs; the former are nearly as long as broad and separated from the fixed cheeks by the strong ocular ridges; the postero-lateral limbs and fixed cheeks merge into each other so as to form subtriangular areas, with the narrow palpebral lobes on their front outer margins for about one-third of their length; the palpebral lobes are small, about one-fourth to one-fifth the length of the cranidium and bordered by a strong, narrow, rounded rim that extends across the fixed cheeks to the dorsal furrow, beside the glabella.

Glabella large, a little wider in front than at the occipital furrow and with slightly diverging sides; front broadly rounded; surface marked by four pairs of furrows, the posterior of which extends obliquely inward across the posterior portion nearly to the center, so as to separate a small subtriangular lobe on each side; the three anterior pairs of furrows are short, close to the dorsal furrow, and about equal distances from each other. Occipital ring very narrow at its ends, from where it broadens rapidly to its full width; a short, oblique furrow occurs on each side that is subparallel to the posterior pair of glabellar furrows, that serve to separate the central portion of the occipital ring from its end sections; occipital furrow narrow, distinct, transverse, and terminating in advance of the posterior intermarginal furrows of the fixed cheeks. Free cheeks small, elongate, and with rounded posterior angles; eye lobes small. The facial sutures cut the posterior margin just within the genal angle and extend obliquely forward and inward with a slight sigmoid

[1] This British Columbia horizon is given in detail in the Formation and locality of *Burlingia hectori*.

curvature to the base of the eye lobes; curving over and around the eye lobes, they pass forward and a little outward to the front margin; the distance between the eye lobes and margin is about the length of the eye lobe.

Thorax with eight segments; axial lobe moderately convex, about as wide as the pleural lobes in partially compressed specimens; on the outer side of each segment a rounded, transverse node or ridge is separated from the main body of the segment by a slightly oblique furrow transverse to the segment; the furrows are similar to those crossing the occipital ring; pleural lobes slightly convex and with the extremities of the pleuræ bending slightly downward; each pleura has very narrow, raised margins next to the axial lobe that gradually broaden and slope inward out to the slight geniculation, where they form an elongated node with straight outer edge, which, touching against the nodes upon the adjoining pleura, forms an elongated, rounded node transversely divided by the line separating the pleuræ; an elongated, tapering, rounded node, with its base at the dorsal furrow, occupies the inner half of the pleura; a narrow groove on each side of the node united to form a shallow pleural furrow that terminates within the somewhat abruptly pointed outer extremity of each pleura.

Pygidium of medium size, about one-fourth the length of the dorsal shield; anterior margin nearly transverse, except where it bends backward near the outer ends; posterior outline semicircular; axial lobe moderately convex and tapering gradually toward the posterior section; it is divided by four transverse furrows into four rings and a terminal segment; four anchylosed pleural segments are outlined on the pleural lobes on each side of the axial lobe by furrows that progressively curve backward from the first to the posterior adjoining the terminal segment; the furrows all terminate within the narrow, slightly flattened border.

Surface finely granulose.

DIMENSIONS.—A dorsal shield 13.5 mm. in length has the following dimensions:

	mm.
Cephalon:	
Length	5.0
Length of eye lobe	0.9
Width at posterior margin	9.0
Width of glabella at posterior margin	2.4
Thorax:	
Length	5.5
Width	8.5
Width of axial lobe at first segment	2.3
Width of axial lobe at eighth segment	1.9

Pygidium:	mm.
Length	2.9
Width at union with thorax	6.0

OBSERVATIONS.—This species is rather rare at Mount Stephen, although 18 specimens were found in the collections of 1907. The largest specimen of the dorsal shield has a length of 18 mm. The strong triangular nodes on the pleural portion of the segments next to the axial lobe and the nodes at the geniculation, combined with the clearly defined furrows about them, give the thorax a very striking ornamental effect that leads to giving the specific name *ornatus*. This type of thoracic segment serves to distinguish the species from all other species of the genus *Bathyuriscus*. The associated *B. rotundatus* (Rominger)[1] has quite a different pleural segment, larger pygidium in proportion to the length of the dorsal shield, and nine thoracic segments instead of the eight, as in *B. ornatus*.

Another associated species, *Bathyuriscus occidentalis* (Matthew),[2] has nine segments with an open pleural furrow, relatively smaller pygidium, and larger free cheek.

FORMATION AND LOCALITY.—Middle Cambrian: Ogygopsis shale of the Stephen formation, 2,400 feet (731.5 m.) above the Lower Cambrian and 2,600 feet (792.5 m.) below the Upper Cambrian; northwest slope of Mount Stephen, 3,000 feet (914.4 m.) above the Kicking Horse River, above Field, on the Canadian Pacific Railway, British Columbia, Canada.

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[1] *Embolimus rotundatus* Rominger, 1887, Proc. Acad. Nat. Sci. Philadelphia, p. 16.

[2] *Dolichometopus occidentalis* Matthew, 1899, Trans. Roy. Soc. Canada for 1899, 2d ser., vol. v, sec. 4, No. 2, p. 49.

DESCRIPTION OF PLATE 1

Page

Bathyuriscus ornatus, new species 39

FIG. 1. A broken specimen, showing character of cephalon and thorax. U. S. National Museum, Catalogue No. 53420.

2. A small nearly entire dorsal shield, with the exception of the free cheeks. U. S. National Museum, Catalogue No. 53421.

3. Two segments of the thorax enlarged to show the details of the axial and pleural lobes. U. S. National Museum, Catalogue No. 53423.

The specimens represented by figures 1–3 are from the Middle Cambrian Ogygopsis shale of the Stephen formation, 2,400 feet (731.5 m.) above the Lower Cambrian, on the northwest slope of Mt. Stephen, near Field, British Columbia.

Albertella bosworthi, new genus and new species 22

FIG. 4. Cephalon, showing character of the palpebral lobes. Compare this with the cephalon of *Albertella helena* on pl. 2, figs. 1, 4, and 5. U. S. National Museum, Catalogue No. 53413.

5. A specimen showing the character of the thorax and pygidium. U. S. National Museum, Catalogue No. 53416.

6. Pygidium, which compare with pygidium of *A. helena* pl. 2, fig. 2. U. S. National Museum, Catalogue No. 53415.

7. Inner side of a very small pygidium. U. S. National Museum, Catalogue No. 53406.

The specimens represented by figures 4–7 are from a drift block of Lower Cambrian shales found on the slopes of Mt. Bosworth, just north of the Canadian Pacific Railway, one mile (0.62 km.) east of Hector, British Columbia.

Burlingia hectori, new genus and new species 15

FIG. 8. A nearly entire specimen greatly enlarged. U. S. National Museum, Catalogue No. 53418.

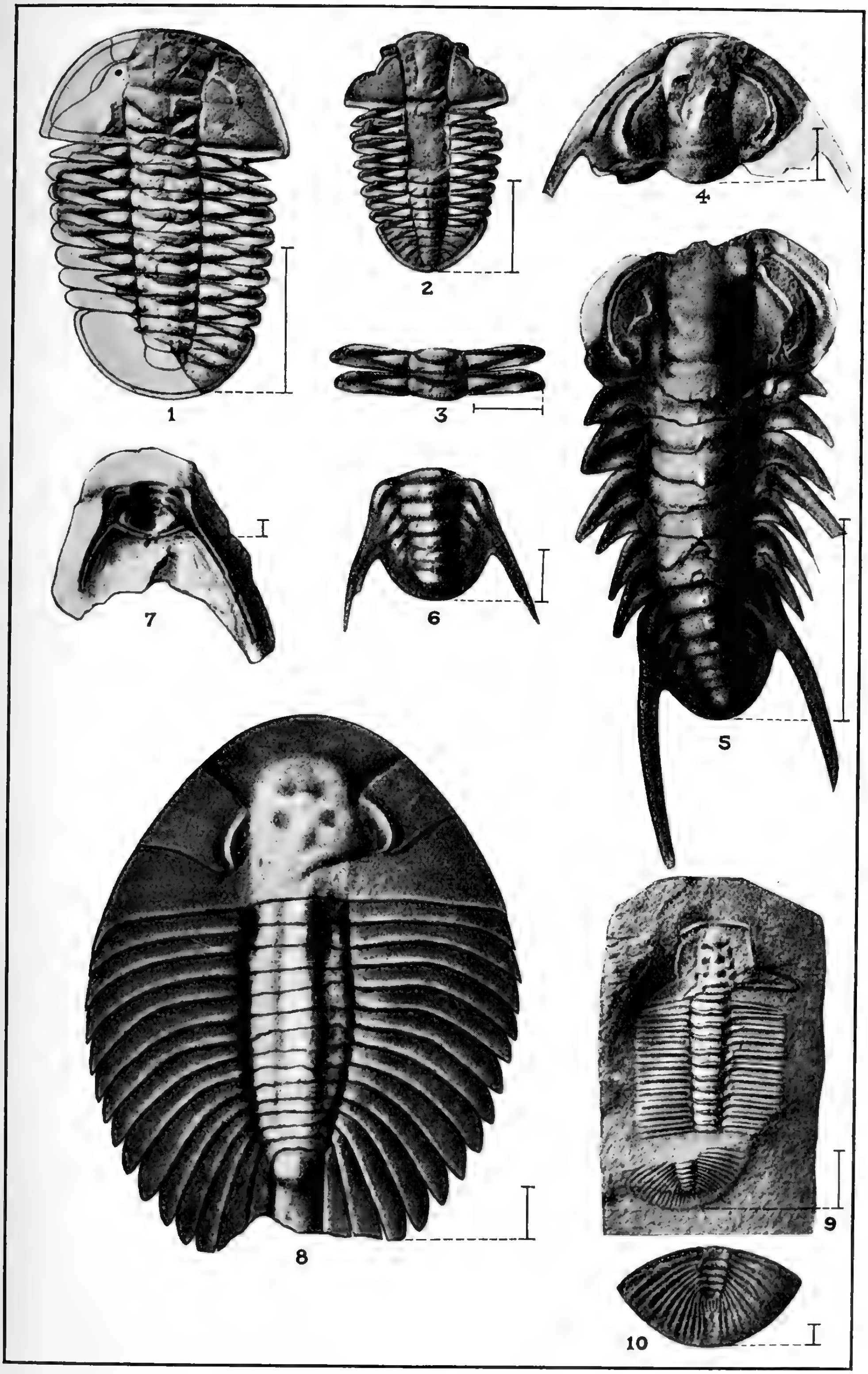
The specimen represented by figure 8 is from the Middle Cambrian Ogygopsis shale of the Stephen formation, 2,400 feet (731.5 m.) above the Lower Cambrian, on the northwest slope of Mt. Stephen, near Field, British Columbia.

Oryctocara geikiei, new genus and new species 23

FIG. 9. A nearly entire dorsal shield with the exception of the free cheeks. U. S. National Museum, Catalogue No. 53426.

10. Greatly enlarged matrix of a small pygidium. U. S. National Museum, Catalogue No. 53427.

The specimens represented by figures 9–10 are from the Spence shale of the Ute formation, near the base of the Middle Cambrian, in a ravine running up into Danish Flat from Mill Canyon, about 15 miles (9.37 km.) west of Montpelier, and 5 miles (3.12 km.) west-southwest of Liberty, Bear Lake County, Idaho.



CAMBRIAN TRILOBITES

DESCRIPTION OF PLATE 2

Page

Albertella helena, new genus and new species 19

FIG. 1. A nearly entire dorsal shield. U. S. National Museum, Catalogue No. 53410.

2. A pygidium retaining much of its natural form. The outer test is exfoliated about the margins. U. S. National Museum, Catalogue No. 53411.

3. A very small dorsal shield. U. S. National Museum, Catalogue No. 53409.

4. A large, broken dorsal shield. U. S. National Museum, Catalogue No. 53407.

5. A large cranidium. U. S. National Museum, Catalogue No. 53408.

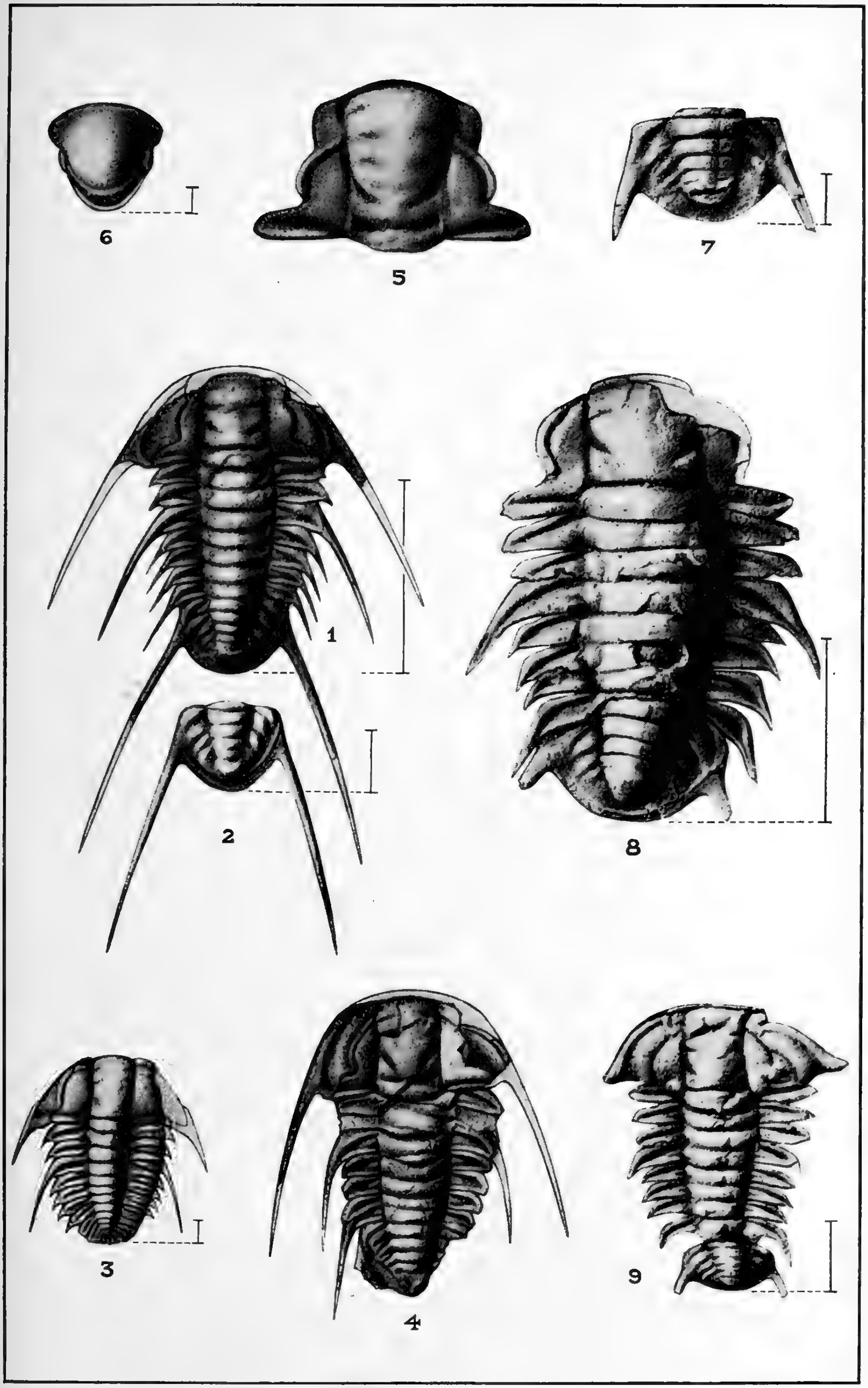
6. Hypostoma associated with this species. U. S. National Museum, Catalogue No. 53414.

7. A pygidium which compare with the pygidium of *A. bosworthi* on pl. 1, fig. 6. U. S. National Museum, Catalogue No. 53403.

8. A broken dorsal shield, broadened by compression. U. S. National Museum, Catalogue No. 53402.

9. A small dorsal shield. U. S. National Museum, Catalogue No. 53404.

The specimens represented by figures 1–5 are from Lower Cambrian shales on Gordon Creek, Ovando Quadrangle, Powell County, Montana, and those represented by figures 6–9 are from a drift block of Lower Cambrian shales found on the slopes of Mt. Bosworth, just north of the Canadian Pacific Railway, one mile (0.62 km.) east of Hector, British Columbia.



CAMBRIAN TRILOBITES

DESCRIPTION OF PLATE 3

Page

Zacanthoides idahoensis 26

FIG. 1. A large dorsal shield compressed in the shale. U. S. National Museum, Catalogue No. 53434.

2. A small dorsal shield with seven thoracic segments and three spines on each side of pygidium. U. S. National Museum, Catalogue No. 53437.

3. Small dorsal shield with adult characters. U. S. National Museum, Catalogue No. 53435.

4. Small dorsal shield with adult characters. U. S. National Museum, Catalogue No. 53436.

5. Dorsal shield of a very young individual with a strong spine on the axial lobe of the fifth segment. U. S. National Museum, Catalogue No. 53440.

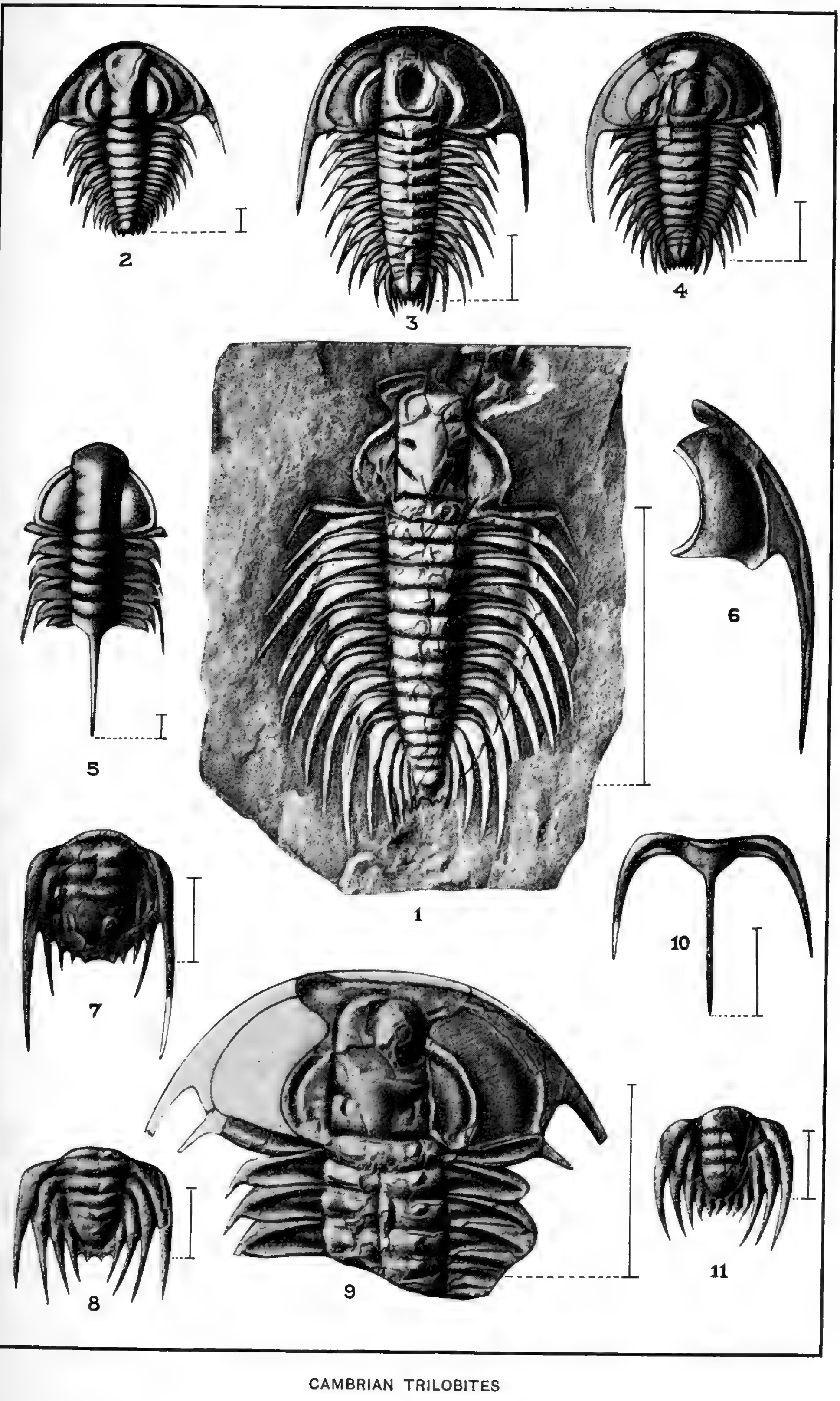
6. Large free cheek. U. S. National Museum, Catalogue No. 53432.

FIGS. 7, 8, and 11. Pygidia illustrating variations in spinose border. U. S. National Museum, Catalogue Nos. 53429, 53430, and 53431.

FIG. 9. Fragment of a large adult dorsal shield showing interocular spine, free cheek in position, and the lateral position of the genal spine on the free cheek. U. S. National Museum, Catalogue No. 53433.

10. Fifth thoracic segment with median spine. U. S. National Museum, Catalogue No. 53438.

The specimens represented by figures 1–10 are from the Spence shale of the Ute formation, near the base of the Middle Cambrian, in a ravine running up into Danish Flat from Mill Canyon, about 15 miles (9.37 km.) west of Montpelier, and 5 miles (3.12 km.) west-southwest of Liberty, Bear Lake County, Idaho.



CAMBRIAN TRILOBITES

DESCRIPTION OF PLATE 4

FIG. 1. A nearly entire dorsal shield with the occipital spine broken off. U. S. National Museum, Catalogue No. 53383.

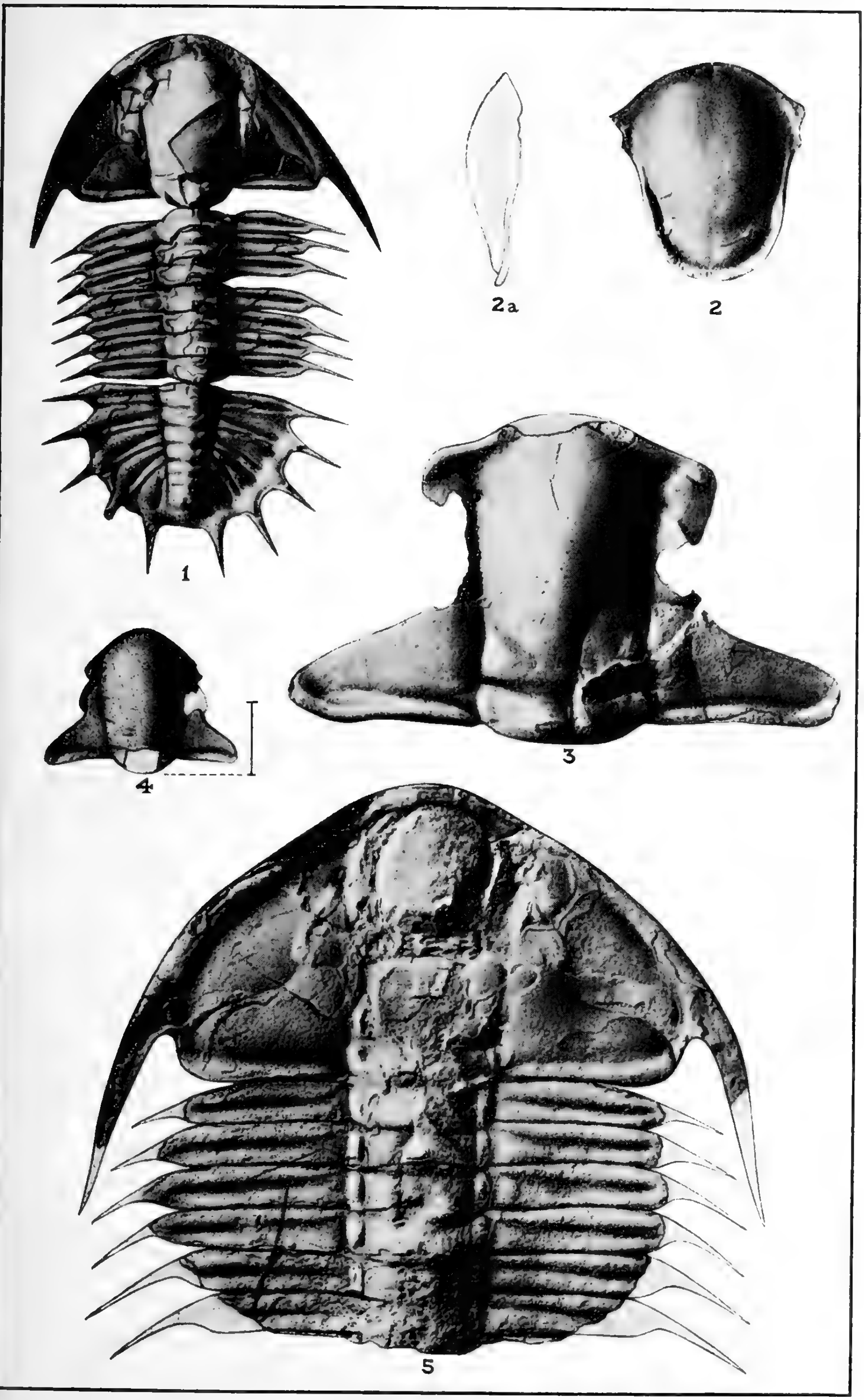
FIGS. 2 and 2*a*. Hypostoma associated with this species. U. S. National Museum, Catalogue No. 53381.

FIG. 3. Large compressed cranidium. U. S. National Museum, Catalogue No. 53384.

4. Small convex cranidium. U. S. National Museum, Catalogue No. 53382.

5. Portion of a large dorsal shield with well preserved outline of the cephalon. U. S. National Museum, Catalogue No. 53380.

The specimens represented by figures 1–5 are all from thin-bedded Middle Cambrian limestones of the Marjum formation, 2,140 feet (652.3 m.) above the top of the Lower Cambrian, in ridge on east side of Wheeler Amphitheater, east of Antelope Springs, House Range, Millard County, Utah.



CAMBRIAN TRILOBITES

DESCRIPTION OF PLATE 5

Fig. 1. A small nearly entire dorsal shield with the exception of the free cheeks. U. S. National Museum, Catalogue No. 53390.

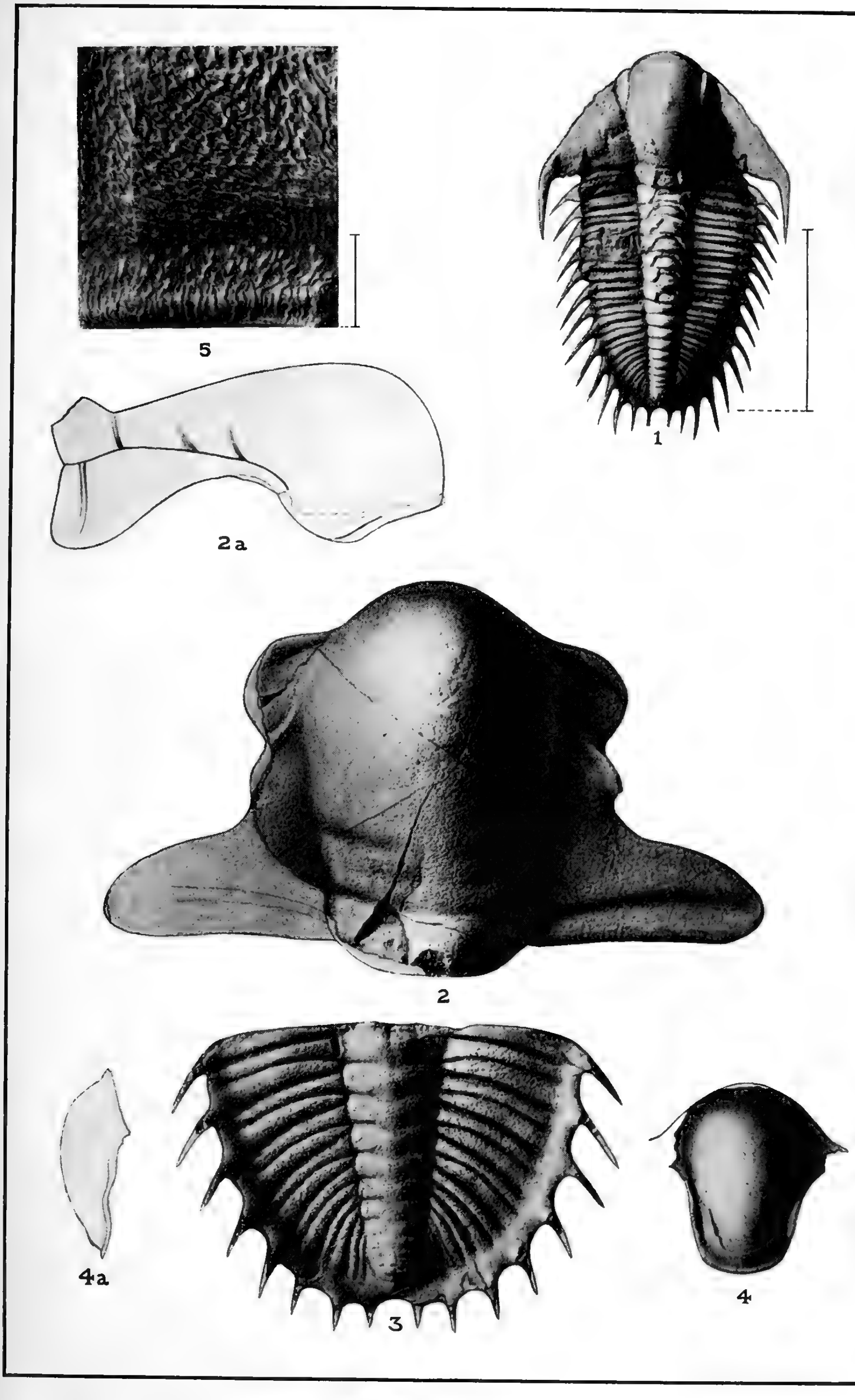
Figs. 2 and 2*a*. A large cranidium. U. S. National Museum, Catalogue No. 53389.

Fig. 3. A characteristic pygidium. U. S. National Museum, Catalogue No. 53388.

Figs. 4 and 4*a*. Associated hypostoma. U. S. National Museum, Catalogue No. 53386.

5. Enlargement of the exterior ornamentation of the surface of the fixed cheek back of the palpebral lobe. U. S. National Museum, Catalogue No. 53387.

The specimen represented by figure 1 is from thin-bedded Middle Cambrian limestones 2,300 feet (701 m.) above the Lower Cambrian; and the specimens represented by figures 2–5 are from thin-bedded Middle Cambrian limestones 2,140 feet (652.3 m.) above the top of the Lower Cambrian, both in the Marjum formation, in the ridge on east side of Wheeler Amphitheater, east of Antelope Springs, Millard County, Utah.



CAMBRIAN TRILOBITES

DESCRIPTION OF PLATE 6

Page

Neolenus intermedius, new species.................................... 34

FIG. 1. Cranidium and thorax; natural size. U. S. National Museum, Catalogue No. 53397.

2. Cranidium; natural size. U. S. National Museum, Catalogue No. 53394.

3. A pygidium with five marginal spines. Compare this pygidium with that of *Neolenus superbus* on pl. 4, fig. 1. U. S. National Museum, Catalogue No. 53398.

4. A pygidium with six marginal spines that is doubtfully referred to this species. U. S. National Museum, Catalogue No. 53392.

5. A small convex cranidium doubtfully referred to this species. U. S. National Museum, Catalogue No. 53395.

6. A small cranidium with a strong occipital node. U. S. National Museum, Catalogue No. 53396.

7. Hypostoma associated with this species. U. S. National Museum, Catalogue No. 53393.

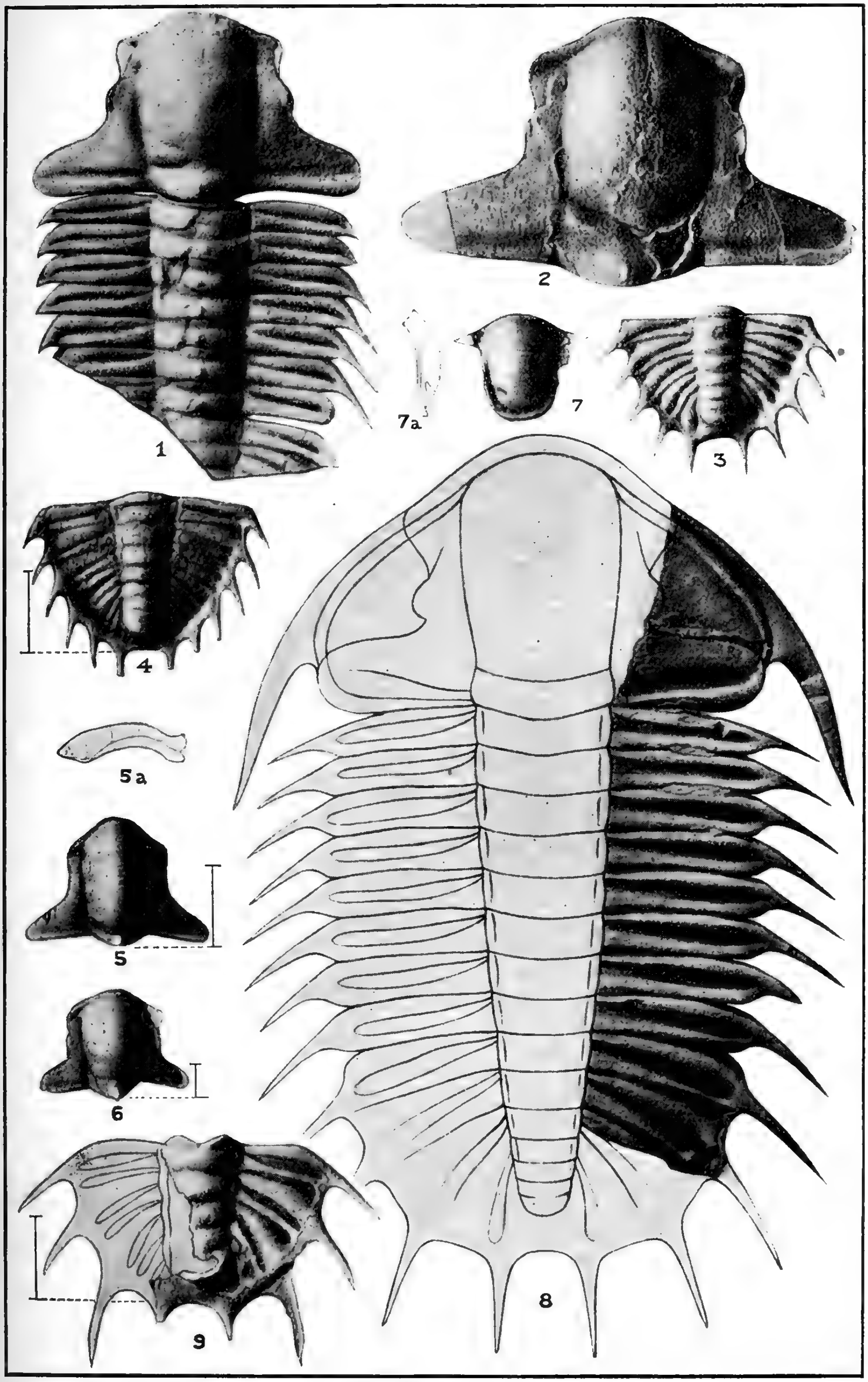
The specimen represented by figure 6 is from thin-bedded Middle Cambrian limestones 2,075 feet (632.5 m.) above the Lower Cambrian; that represented by figure 5 is from thin-bedded Middle Cambrian limestones 2,140 feet (652.3 m.) above the Lower Cambrian; and those represented by figures 1–4, and 7 are from thin-bedded Middle Cambrian limestones 2,300 feet (701 m.) above the Lower Cambrian; all in the Marjum formation, in ridge on east side of Wheeler Amphitheater, east of Antelope Springs, House Range, Millard County, Utah.

Neolenus intermedius pugio, new variety.................................... 35

FIG. 8. Fragment of a large dorsal shield with missing parts restored in outline. U. S. National Museum, Catalogue No. 53400.

9. A broken pygidium. U. S. National Museum, Catalogue No. 53401.

The specimens represented by figures 8 and 9 are from thin-bedded Middle Cambrian limestones of the Marjum formation, 2,300 feet (701 m.) above the Lower Cambrian, in ridge on east side of Wheeler Amphitheater, east of Antelope Springs, House Range, Millard County, Utah.



CAMBRIAN TRILOBITES

CORRECTIONS TO BE INSERTED IN SMITHSONIAN MISCELLANEOUS COLLECTIONS, VOLUME LIII.

NOTE.—This slip is so arranged that it may be torn apart and pasted in papers Nos. 1, 2, and 3.

CAMBRIAN GEOLOGY AND PALEONTOLOGY. WALCOTT.

No. 1.—NOMENCLATURE OF SOME CAMBRIAN CORDILLERAN FORMATIONS.

Page 2. The Mount Whyte formation which is placed in the Middle Cambrian on page 2 should be in the Lower Cambrian as indicated on page 4.

CAMBRIAN GEOLOGY AND PALEONTOLOGY. WALCOTT.

No. 2.—CAMBRIAN TRILOBITES.

Page 22. 17th line, strike out "Wolsey."
" 22. 18th line, (2.5 km.) should read (6.44 km.)
" 26. 4th and 5th lines,
" 30. 9th and 10th lines,
" 42. 43d and 44th lines,
" 46. 29th and 30th lines,
(9.37 km.) and (3.12 km.) should read (24.14 km.) and (8.05 km.), respectively.
" 33. 33d line,
" 35. 6th line,
" 35. 28th line,
" 38. 41st line,
(605–653.8 m.) should read (577.6–652.3 m.)
" 42. 27th line,
" 44. 27th line,
(0.62 km.) should read (1.61 km.)

CAMBRIAN GEOLOGY AND PALEONTOLOGY. WALCOTT.

No. 3.—CAMBRIAN BRACHIOPODA: DESCRIPTIONS OF NEW GENERA AND SPECIES.

Page 57. 32d line, "base of the Wolsey shale" should read "top of the quartzitic sandstones."
" 101. 18th line, strike out "Wolsey." The shale mentioned on these pages is not the equivalent of the Wolsey shale.

SMITHSONIAN MISCELLANEOUS COLLECTIONS

PART OF VOLUME LIII

CAMBRIAN GEOLOGY AND PALEONTOLOGY

No. 3.—CAMBRIAN BRACHIOPODA: DESCRIPTIONS OF NEW GENERA AND SPECIES

WITH FOUR PLATES

BY

CHARLES D. WALCOTT

No. 1810

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
OCTOBER 1, 1908

CAMBRIAN GEOLOGY AND PALEONTOLOGY

No. 3.—CAMBRIAN BRACHIOPODA: DESCRIPTIONS OF NEW GENERA AND SPECIES

By CHARLES D. WALCOTT

(With Four Plates)

This is the eighth paper resulting from the preliminary studies for Monograph 51 of the U. S. Geological Survey. I expect to use many new generic and specific names in lists of fossils occurring in geologic sections and in a forthcoming paper on the classification of the Brachiopoda, and think it is best to describe the fossils before using their names elsewhere.

The paper on the classification will be the last of the preliminary papers, as the monograph is now in the editor's hands and should appear in 1909.

The previous papers in this series are:

I. Note on the genus *Lingulepis.* American Jour. Sci., 4th ser., III, 1897, pp. 404–405.

II. Cambrian Brachiopoda: Genera *Iphidia* and *Yorkia,* with descriptions of new species of each, and of the genus *Acrothele.* Proc. U. S. National Museum, XIX, 1897, pp. 707–718.

III. Note on the brachiopod fauna of the quartzitic pebbles of the Carboniferous conglomerates of the Narragansett Basin, Rhode Island. American Jour. Sci., 4th ser., VI, 1898, pp. 327–328.

IV. Cambrian Brachiopoda: *Obolus* and *Lingulella,* with descriptions of new species. Proc. U. S. National Museum, XXI, 1898, pp. 385–420.

V. Cambrian Brachiopoda: *Obolella,* subgenus *Glyptias; Bicia; Obolus,* subgenus *Westonia;* with descriptions of new species. Proc. U. S. National Museum, XXIII, 1901, pp. 669–695.

VI. Cambrian Brachiopoda: *Acrotreta; Linnarssonella; Obolus;* with descriptions of new species. Proc. U. S. National Museum, XXV, 1902, pp. 577–612.

VII. Cambrian Brachiopoda, with descriptions of new genera and species. Proc. U. S. National Museum, XXVIII, 1905, pp. 227–337.

There are also a number of Cambrian brachiopoda described in two papers on the Cambrian faunas of China:

Cambrian Faunas of China. Proc. U. S. National Museum, XXIX, 1905, pp. 1–106.

Cambrian Faunas of China. Proc. U. S. National Museum, XXX, 1906, pp. 563–595.

Genus MICKWITZIA Schmidt [1888, p. 24]

MICKWITZIA OCCIDENS, new species

PLATE 7, FIGURE 1

There are only crushed and broken specimens of this shell. One of these shows that the apex of the ventral valve was a little above the posterior margin of the shell, very much as in *Mickwitzia pretiosa.* The outline of the valves appears to have been ovate to subcircular, with the ventral valve moderately convex. The shell is phosphatic or chitinous and built up of three principal layers. The outer layer is thin and thickly set with minute pustules or granules that give the surface a roughened appearance. When the outer layer is exfoliated, which is usually the case, the middle layer presents a smooth, shining surface that is marked by a few concentric striæ and numerous fine radiating striæ, between which many very minute punctæ occur. The inner layer shows minute, irregular, serpentine, rounded ridges, perforated by vertical canals or punctæ. An interior of a ventral valve shows the lines of advance of the anterolateral muscle scars. The largest shell indicated on the surface of the siliceous shale has a length and width of 12 mm.

This species and the generic reference is based on the character of the apex of the ventral valve and the structure and character of the shell.

FORMATION AND LOCALITY.—Lower Cambrian: (1) Near the base of the section, about 5,500 feet (1,676.4 m.) below the top of the Lower Cambrian, in shaly indurated sandstones, one mile (1.61 km.) east of the Saline Valley road, and 2 to 3 miles (3.22 to 4.83 km.) east-northeast of Waucoba Springs, Inyo County, California. (2) *Sandstones on small hill in the salt flat one mile (1.61 km.) northeast of Silver Peak Mill, Silver Peak quadrangle (U. S. G. S.), Esmeralda County, Nevada.*[1]

MICKWITZIA PRETIOSA, new species

PLATE 7, FIGURE 2

This species is founded on a single specimen of a ventral valve. It has a length of 7 mm.; width, 6.5 mm. Outline subcircular, slightly convex; apex curved over toward the posterior margin and projecting beyond it. False area short and obscure. Surface marked by radiating, raised lines, that at the front margin show six

[1] Where there is more than one locality, the one from which the type specimens come is italicised.

in a distance of two millimeters. Fine papillæ are thickly scattered over the surface. They have a tendency to follow concentric lines of growth on some portions of the shell, and on others they appear on low, narrow, serpentine ridges, as in *Mickwitzia monilifera* (Linnarsson) [1869, p. 344]. A few large punctæ are scattered here and there over the surface. Inner surfaces and layers of shell unknown.

This beautiful shell differs in the details of its surface from *M. monilifera;* it is also less convex and the apex is nearer the posterior margin.

FORMATION AND LOCALITY.—Lower Cambrian: Eophyton sandstone, at Lugnås, Vestergotland, Sweden.

Genus MICROMITRA Meek [1873, p. 479].

MICROMITRA HAYDENI, new species

PLATE 7, FIGURES 3 AND 3*a*

Ventral valve subconical, with a minute beak arching slightly over a strong, arched pseudodeltidium, which is about one-half as long as the height of the valve. Cardinal slope rounded; a slight angle is indicated by a line where the concentric surface striæ bend inward toward the pseudodeltidium across the narrow area; a sharp angle is formed where the convex pseudodeltidium rises abruptly from the area.

Dorsal valve moderately convex, most elevated at the small umbo just in advance of the marginal, minute beak; area very low and narrow and without trace of pseudodeltidium as far as now known.

Surface marked by fine, concentric, slightly undulating, thread-like striæ and a varying number of irregular, more or less interrupted, narrow, depressed, rounded, radiating ridges; these ridges are usually most numerous at the central portions of the valves. The concentric striæ extend across the narrow area and arch over the pseudodeltidium, where they are finer and crowded together, so that all the striæ between the apex and the front margin are compressed in about one-half the distance on the pseudodeltidium. The adult ventral valve is about 4.5 mm. in length by 5 mm. in width and 2.5 mm. in height, with a pseudodeltidium 1.3 mm. in length. A dorsal valve 2 mm. in length has a height of about 0.5 mm. at the umbo. The shell is rather thick for a species of this size and it is built up of several thin layers or lamellæ.

OBSERVATIONS.—*Micromitra haydeni* differs from the nearest related species, *M. sculptilis* (Meek) [1873, p. 479], in having a strong,

convex pseudodeltidium, less elevation of the ventral valve, and a thicker shell. *M. haydeni* occurs near the base of the Middle Cambrian and *M. sculptilis* about 2,000 feet (609.6 m.) higher in the section of the Cambrian rocks of Utah and southern Idaho.

The specific name is given in honor of Dr. F. V. Hayden, geologist and explorer, under whose charge the geology of this region was first studied.

Formation and Locality.—Middle Cambrian: Limestone of the Langston formation, just above the Cambrian quartzitic sandstone beds, north side of Two Mile Canyon, near its mouth, 2 miles (3.22 km.) southeast of Malad, Oneida County, Idaho.

MICROMITRA SCULPTILIS ENDLICHI, new variety

This form is represented by a single specimen of a ventral valve. The surface is similar to that of *Micromitra sculptilis* (Meek) [1873, p. 479], but the valve is more elongate, less elevated, and larger (5 mm. in diameter) than the specimens of the latter from the type locality.

Formation and Locality.—Upper Cambrian: Limestone 2 miles (3.22 km.) north of Aurum, Schell Creek Range, White Pine County, Nevada.

Subgenus IPHIDELLA Walcott [1905*a*, p. 304]

MICROMITRA (IPHIDELLA) LOUISE, new species

Plate 7, Figures 4 and 4*a*

In form this species is not unlike *Micromitra pealei* (Walcott) [1897*b*, p. 712] and the more elongate forms of *M.* (*Iphidella*) *pannula maladensis* (Walcott) [1905*a*, p. 306]. It differs from both species mentioned in its surface characters. In the latter respect it is more like *M.* (*I.*) *nyssa* (see p. 57), but the form of *M.* (*I.*) *louise* is more elongate and the apex of the ventral valve is nearer to the posterior margin; the shell also appears to have been thicker. The surface characters are exceedingly minute. Under a glass magnifying twenty diameters, the surface looks much like that of *M.* (*I.*) *pannula* (White) [1874, p. 6]. The largest ventral valve in the collection has a length of 7.5 mm. and a width of 7 mm.; elevation, 1 mm.

Micromitra (*Iphidella*) *louise* is the oldest brachiopod known from the Cambrian of the Canadian Rocky Mountains. In the Lakes Louise and Agnes section it is 3,100 feet (944.9 m.) below the summit of the Lower Cambrian and 2,750 feet (838.2 m.) below the

horizon which, on the basis of the associated faunas, is correlated with that at which *M.* (*I.*) *nyssa* occurs in Montana. It occurs in a fine, hard, dark gray, siliceous shale in association with *Hyolithes, Cruziana,* and a fragment indicating the free cheek of a trilobite.

FORMATION AND LOCALITY.—Lower Cambrian: Siliceous shale of the Lake Louise formation [Walcott, 1908*a*, p. 5], 3,100 feet (944.9 m.) below the summit of the Lower Cambrian, in cliff rising from the southwest shore of Lake Louise, south of Laggan, on the Canadian Pacific Railway, Alberta, Canada.

MICROMITRA (IPHIDELLA) NYSSA, new species

PLATE 7, FIGURE 5

Ventral valve subcircular in outline, with the posterior margin almost transverse; form depressed conical, with a minute beak incurving over the pseudodeltidium. The cardinal slope is compressed in all the specimens, but it indicates that there was an imperfectly defined narrow area. Pseudodeltidium, as far as can be determined, broad and short, with its lower margin broadly arched. Dorsal valve slightly convex, beak marginal. No traces of a false area or pseudodeltidium have been observed.

Surface marked by concentric striæ and lines of growth that are crossed obliquely by two sets of fine elevated lines. The crossing of the latter lines forms minute, shallow, rhomboidal pits, which give to the surface the appearance of a fine network. On the ventral valve the striæ cross the pseudodeltidium. Shell substance corneous.

OBSERVATIONS.—This is one of the largest shells of this genus. The ventral valve has a length of 11 mm. and a width of 13 mm. In form it resembles *Micromitra* (*Paterina*) *labradorica* (Billings) [1861*b*, p. 6], and in surface characters, *M.* (*Iphidella*) *ornatella* (Linnarsson) [1876, p. 25] and some varieties of *M.* (*I.*) *pannula* (White) [1874, p. 6].

FORMATION AND LOCALITY.—Middle Cambrian: About 200 feet (61 m.) above the base of the Wolsey shale, on ridge between Gordon and Young creeks, about half way between Gordon Mountain summit and Cardinal Peak, Ovando quadrangle (U. S. G. S.), Powell County, Montana.

Subgenus PATERINA Beecher [1891, p. 345]

MICROMITRA (PATERINA) STUARTI, new species

PLATE 7, FIGURES 8 AND 8*a*

Ventral valve subconical, with a minute beak arching slightly over a short pseudodeltidium. Cardinal slope with a rounded angle that extends from the beak to the postero-lateral margin and defines a very narrow, flattened area on each side of a high, triangular fissure that is covered for a short distance at the top by a very short, arched pseudodeltidium.

Dorsal valve rather strongly convex for a species of this genus; the highest part is at about the center of the shell, from where the slope is very slight to the beak and rather rapid to the front margin. Beak marginal above a low, broad arching of the posterior margin of the shell; area shown only by a very narrow margin where the shell bends toward the median line; no trace of a pseudodeltidium has been observed.

Surface marked by narrow, rounded, concentric thread-like striæ or ridges with short striæ between them. Shell substance corneous.

The average size of adult shells is 8 mm. long by about the same width.

OBSERVATIONS.—This is one of the larger species of the genus; it occurs quite abundantly in a compact, bluish-gray limestone in the lower portion of the Middle Cambrian terrane. *Micromitra* (*Paterina*) *superba* (Walcott) [1897*b*, p. 711] occurs 16 feet (4.8 m.) below and *M.* (*Iphidella*) *pannula* (White) [1874, p. 6] 70 feet (21.3 m.) below in the same section.

This fine shell has a short pseudodeltidium much like that of *M.* (*P.*) *logani* (Walcott) [1897, p. 711], but it differs in form and greater size; the same is true of *M.* (*P.*) *crenistria* (Walcott) [1897, p. 713]. It may be closely related to *M.* (*P.*) *labradorica utahensis* (Walcott) [1905, p. 306], but the specimens of the latter are too imperfect for close comparison of form.

The specific name is given for my son Benjamin Stuart, who assisted me in collecting the specimens during the summer of 1906.

FORMATION AND LOCALITY.—Middle Cambrian: Limestones of the Ute formation [Walcott, 1908*a*, p. 7], 185 feet (56.4 m.) above the Cambrian quartzitic sandstone beds, in Blacksmith Fork Canyon, about 8 miles (12.87 km.) above its mouth and 15 miles (24.14 km.) east of Hyrum, Cache County, Utah.

MICROMITRA (PATERINA) WAPTA, new species

PLATE 7, FIGURE 6

Shell large and thick for a species of this genus. Ventral valve depressed conical, with the apex above a narrow false area that is outlined by the abrupt curvature of the shell. As the shells usually occur compressed in the siliceous shale, the false area is concealed and the posterior slopes from the apex form a blunt angle at the apex. Dorsal valve transverse, moderately convex, with the posterior margin nearly straight and a little shorter than the greatest width of the valve; beak small, marginal; cardinal slope and false area unknown.

Surface marked by concentric, slightly irregular, rounded lines and ridges of growth that are grouped in bands of varying width; a few radiating striæ or lines occur on the central portions of one ventral valve; with a lens magnifying 20 diameters, an occasional roughness can be seen in reflected light on the surface of some of the concentric ridges.

OBSERVATIONS.—This is one of the largest species of the genus. One ventral valve has a length and breadth of 14 mm. and several are 9 to 11 mm. in diameter. It compares in size with *Micromitra (Iphidella) nyssa* (see p. 57), from the same geological horizon in Montana, but the latter has a reticulate exterior surface of the *M. (I.) pannula* (White) [1874, p. 6] type. It was at first thought that this species might be the old shells of *Acrothele colleni,* new species, but a careful comparison with the younger stages of growth of *M. (P.) wapta* shows that the latter has only indefinite traces of the highly ornate surface of *Acrothele colleni,* and that the apex of the ventral valve of *M. (P.) wapta* is imperforate and over the posterior margin and not on the general surface of the valve in advance of the margin, as in *Acrothele colleni.* The two species were found associated on Mount Bosworth. *M. (P.) wapta* is of the same type as *M. (P.) labradorica* (Billings) [1861*b,* p. 6], *M. (P.) prospectensis* (Walcott) [1884, p. 19], and *M. (P.) stissingensis* (Dwight) [1889, p. 145]. It differs from all in having more irregular, less definite threadlike concentric lines, and in the manner in which the striæ are assembled in ridges.

FORMATION AND LOCALITY.—Lower Cambrian: Drift block of siliceous shale supposed to have come from the Mt. Whyte formation [Walcott, 1908*a,* p. 4], south slope of Mount Bosworth, on the Continental Divide, one mile (1.61 km.) west of Stephen, on the Canadian Pacific Railway, British Columbia, Canada.

MICROMITRA (PATERINA) WILLIARDI, new species

Plate 7, Figure 7

Iphidella major Walcott (in part), 1905, Proc. U. S. National Museum, XXVIII, p. 304. (Specimens now referred to *M.* (*P.*) *williardi* were included with the specimens representing *M.* (*P.*) *major* when this description was written.)

Ventral valve subconical, with the apex over the posterior third of the subcircular margin of the valve; false area narrow, but clearly defined by a rather sharp angle on the cardinal slopes that breaks the curvature of the shell a short distance from the margin of the pseudodeltidium; pseudodeltidium broad, convex, with its lower margin broadly arched, so as to leave a space between it and the general plane of the margin of the shell. Some specimens of the pseudodeltidium are uniformly rounded, in others there is a narrow groove extending from the apex to the base, and on some a very narrow faint ridge is indicated.

Dorsal valve slightly convex, transverse, and slightly rounded at the cardinal margin. No traces of a false area or pseudodeltidium have been observed.

The cast of the interior of the apex of the ventral valve shows a small apical callosity with two radiating grooves extending upward toward the front lateral margin of the shell.

Surface marked by very fine, strong, concentric, elevated striæ. A specimen 10 mm. in diameter shows seven of these elevated striæ in a distance of 1 mm.; the elevated striæ are crossed by very fine transverse striæ; the elevated striæ cross the false area parallel to its base and arch over the pseudodeltidium.

A ventral valve 10.5 mm. in diameter has a height of 2.5 mm.

Observations.—This species is closely related to *Micromitra* (*Paterina*) *superba* (Walcott) [1897*b*, p. 711]. It differs in having a longer pseudodeltidium, more finely elevated striæ on the surface, and a more sharply elevated apex to the ventral valve. It is the Lower Cambrian representative of *M.* (*P.*) *superba*.

The associated fossils are *Obolus smithi* (see p. 62), *Wimanella shelbyensis* (see p. 100), *Micromitra* (*Paterina*) *major* (Walcott) [1905*a*, p. 304], and numerous fragments of two or three species of *Olenellus*.

Formation and Locality.—Lower Cambrian: Montevallo argillaceous shale (1) 4 miles (6.44 km.) south of Helena; and (2) *.25 mile (.40 km.) northeast of Helena;* both in Shelby County, Alabama.

Genus OBOLUS Eichwald [1829, p. 274]

OBOLUS MEMBRANACEOUS, new species

PLATE 7, FIGURE 11

In size and outline this species is somewhat similar to *Obolus feistmanteli* (Barrande) [1879, pl. 106, figs. IV: 1–14; pl. 110, figs. VIII: 1–4], but in its very thin, almost membranaceous shell it differs from that species and all other species of the genus known to me. Seven specimens were collected from a shaly, compact limestone, all as casts. Remnants of the corneous shell are preserved which show it to have been very thin, and the interior casts show that it did not retain any impressions of the animal sufficiently strong to be impressed on the cast. A short, rather narrow cardinal area occurs on both the ventral and dorsal valves. Outer surface smooth, with a few lines of growth. The largest ventral valve has a length of 17 mm., with a width of 22 mm. A less distorted dorsal valve has the same length and width, 15 mm.

FORMATION AND LOCALITY.—Middle Cambrian: 4,250 feet (1295.4 m.) above the top of the Lower Cambrian and 860 feet (262.1 m.) below the Upper Cambrian, in shales of the Eldon formation [Walcott, 1908*a*, p. 3], at the north end of the amphitheater northwest of Mount Bosworth, on the Continental Divide, north of the Canadian Pacific Railway, British Columbia, Canada.

OBOLUS PARVUS, new species

PLATE 7, FIGURES 10 AND 10*a*

Shell small, rarely over 2.5 mm. in diameter, moderately convex, nearly semicircular in outline. Ventral valve a little longer than wide and with the umbo curving gently to the minute marginal beak. Dorsal valve a little wider than long and with apex marginal. Surface marked by minute concentric striæ of growth and an exceedingly fine network of irregular lines, that, with a lens magnifying 20 diameters, gives it the appearance of the surface of *Lingulella* (*Lingulepis*) *longinervis* (Matthew) [1903, p. 133]. Nothing is known of the interior of the valves.

OBSERVATIONS.—This small shell occurs in great abundance with *Micromitra* (*Paterina*) *wapta* (see p. 59), *Wimanella simplex* (see p. 101), *Albertella helena* Walcott [1908*b*, p. 19], and other fossils of the fauna of the upper portion of the Lower Cambrian terrane in the Canadian Rocky Mountains. In form it resembles *Obolus mini-*

mus Walcott [1905*a*, p. 325] from China, but it differs in having a less elongate ventral valve and in its peculiar surface.

FORMATION AND LOCALITY.—Lower Cambrian: (1) 1,250 feet (381 m.) above Lake Agnes, in the shales of the Mt. Whyte formation [Walcott, 1908*a*, p. 4], on the north slope of Mt. Whyte, about 4 miles (6.44 km.) south of Laggan, on the Canadian Pacific Railway, Alberta; and (2) *drift block of shale supposed to have come from the Mt. Whyte formation, on the south slope of Mount Bosworth, on the Continental Divide, one mile (1.61 km.) west of Stephen, on the Canadian Pacific Railway, British Columbia, Canada.*

OBOLUS SMITHI, new species

PLATE 7, FIGURES 9 AND 9*a*

General form broadly ovate, with the ventral valve obtusely acuminate and the dorsal valve subcircular, slightly transverse; convexity apparently moderate, judging from the specimens as they occur slightly flattened out in the calcareous shales. The shell was relatively strong and formed of a number of thin layers or lamellæ that, toward the outer edge of the valve, were more numerous and gave a scaly appearance to the margins of the old shells.

Surface marked by concentric lines of growth and numerous very fine, slightly irregular, undulating, concentric ridges upon which numerous very minute papillæ occur, giving the surface, under a strong magnifying power, the appearance of being minutely granular.

A ventral valve 6 mm. in length has a width of 6.75 mm. A slightly larger dorsal valve 7.5 mm. in length has a width of 8 mm.

As shown in the cast, the area of the ventral valve is very short and divided by a relatively strongly marked, narrow pedicle furrow, the edges of which were elevated slightly above the general plane of the area. The cast of the interior shows that the visceral area was continued by a slight, narrow median ridge; the main vascular sinuses extended rather directly forward from the umbo nearly to the front of the shell, separating very gradually and bounding the interior third of the valve. Nothing has been observed of the muscle scars.

The cast of the dorsal valve shows that it had a very short area that extended well out on the cardinal slopes; that a low central ridge extended a little more than half the length of the shell and was continued by a slight, narrow median ridge; the main vascular sinuses extend directly and obliquely forward well toward the front of the shell in about the same relative position as in the ventral

valve; the position of the transmedian and anterior-lateral muscle scars is indicated about half way between the main vascular sinuses and the postero-lateral margin of the valve.

OBSERVATIONS.—This species is characterized by its finely granular surface, short cardinal area, and relatively thick shell. It has the general form of *Obolus lamborni* (Meek) [1871, p. 185] and *Obolus willisi* (Walcott) [1898*b*, p. 418]. It differs from both of these species in having a granulated surface and shorter cardinal area. It is a Lower Cambrian form, but appears to be represented in the Middle Cambrian by *Obolus willisi* and in the Upper Cambrian by *Obolus lamborni*. The associated fossils are *Wimanella shelbyensis* (see p. 100), *Micromitra* (*Paterina*) *major* (Walcott) [1905, p. 304], *Micromitra* (*Paterina*) *williardi* (see p. 60), and numerous fragments of two or three species of *Olenellus*.

The specific name is given in honor of Prof. E. A. Smith, State Geologist of Alabama.

FORMATION AND LOCALITY.—Lower Cambrian: Montevallo shale (1) 4 miles (6.44 km.) south of Helena; and (2) *along road just north of Buck Creek, .125 mile (.20 km.) northeast of Helena;* both in Shelby County, Alabama.

OBOLUS TETONENSIS LEDA, new variety

This is the Upper Cambrian representative of *Obolus tetonensis* Walcott [1901, p. 684] of the Middle Cambrian of the Teton Mountains. Stratigraphically it occurs over 2,000 feet (609.6 m.) higher in the Cambrian section of the House Range, and the localities are 400 miles (644 km.) apart. The variety *leda* differs from the species in having more numerous, fine, thread-like striæ and in the fact that the ventral valve is usually more obtuse in old shells.

FORMATION AND LOCALITY.—Upper Cambrian: 1,945 to 1,975 feet (592.8 to 601.9 m.) above the Middle Cambrian and 1,340 to 1,370 feet (408.4 to 417.6 m.) below the top of the Upper Cambrian, in the siliceous limestones of the Notch Peak formation [Walcott, 1908*a*, p. 9], on the slopes of Notch Peak, 5 miles (8.05 km.) southwest of Marjum Pass, House Range, Millard County, Utah.

OBOLUS WORTHENI, new species

PLATE 7, FIGURE 17

General form subcircular, with the ventral valve very obtusely acuminate and the dorsal valve slightly transverse, both valves slightly convex; ventral valve with the beak at the posterior margin, which rises slightly from the general plane of the margin of the valve; the minute beak of the dorsal valve is at the posterior margin.

Surface marked by sharp, fine, concentric striæ and fine imbricating lines of growth; on some shells low, irregular, more or less obscure and interrupted radiating ridges occur. Shell of medium thickness and built up of several layers or lamellæ. The average diameter of the valves is 3 mm.

The interior of the ventral valve shows a short, flat area divided midway by a narrow pedicle furrow; the visceral area, which is about one-third the length of the valve, is shown only in outline; the main vascular sinuses are strong and situated about midway between the median line and the lateral margins of the valve; the surface outside the visceral area in both valves is marked by fine concentric furrows and large scattered punctæ, much like those of *Obolus* (*Westonia*) *escasoni* (Matthew) [1901, p. 270]. The interior of the dorsal valve has a short area with a broad pedicle groove; strong, curved main vascular sinuses extend from beneath the area well toward the front of the valve; they are subparallel to the margin and are situated about one-third the distance from the margin to the median line of the valve; the visceral area is outlined in about one-half the length of the valve; a narrow deep sinus extends from each side of the anterior end and then curves outward to the front margin.

Observations.—This shell was at first thought to be the young of *Obolus tetonensis* Walcott [1901, p. 684], but with the finding of a good series it was found to have a nearly circular ventral valve instead of subacuminate, as in *O. tetonensis*, and it is less convex in the same character of matrix. In form *Obolus wortheni* resembles *Obolus discoideus* (Hall and Whitfield) [1877, p. 205], but it differs in being more circular in outline and in having a thinner shell.

Formation and Locality.—Upper Cambrian: Limestone of the St. Charles formation [Walcott, 1908*a*, p. 6] about 250 feet (76.2 m.) above the Middle Cambrian, on the north side of Two Mile Canyon, near its mouth, 2 miles (3.22 km.) southeast of Malad, Oneida County, Idaho.

FORDINIA, new subgenus of OBOLUS

This subgenus of *Obolus* is proposed for species having a *Lingulella*-like outline and form with the development of a tendency to form a platform or thickening in the valves in connection with the attachment of the muscles in the ventral valve, and a thickening in the posterior portion of the dorsal valve back of the central muscle scars. The type of the subgenus, *O.* (*F.*) *perfectus* (see p. 65), has these characters well developed. Another species, *O.* (*F.*) *bellulus* (Walcott) [1905*a*, p. 323], has the cardinal area of the ventral valve more united with the visceral area than it is in *O.* (*F.*) *per-*

fectus and the raised area in the dorsal valve is much smaller. In *O.* (*F.*) *gilberti* (see below) the thickened areas are much smaller than in the other two species. These three species appear to be forms intermediate between *Obolus* and *Elkania.*

Type.—*Obolus* (*Fordinia*) *perfectus,* new species.

OBOLUS (FORDINIA) GILBERTI, new species

Plate 7, Figures 15 and 15*a*

This shell was first thought to belong with *Dicellomus politus* (Hall) [1861, p. 24]. It differs from that species in the character of the interior of the dorsal valve and in the narrowing of the umbo as it merges into the apex. The nearest related species is *Obolus* (*Fordinia*) *bellulus* (Walcott) [1905*a*, p. 323]. It differs from the latter in being more convex and in the narrowing of the umbo toward the apex.

The average size of the ventral valve is from 4 mm. to 5 mm. in length by 3 mm to 4 mm. in width. The dorsal valve is a little shorter than the ventral.

The generic reference is based on the interior of the dorsal valve, which is similar to that of *O.* (*F.*) *bellulus.*

Formation and Locality.—Middle Cambrian: About 3,000 feet (914.4 m.) above the top of the Lower Cambrian and 1,400 feet (526.7 m.) below the Upper Cambrian, in gray, more or less thin-bedded limestones of the Marjum formation [Walcott, 1908*a*, p. 10], south side of Marjum Pass, in cliff southeast of divide, House Range, Millard County, Utah.

OBOLUS (FORDINIA) PERFECTUS, new species

Plate 7, Figure 16

General form elongate oval-biconvex; beaks marginal. Surface marked by concentric lines and striæ of growth that gather irregularly in small ridges on the anterior two-thirds of adult shells; very fine, obscure, radiating lines are preserved on some specimens of the outer surface. A shallow, narrow, median sinus occurs on each valve on which the striæ arch slightly backward. Substance of shell apparently calcareo-corneous. The shell is strong and built up of numerous layers or lamellæ that, except toward the beaks, are oblique to the outer layer.

Ventral valve broad ovate, with a rather blunt subacuminate beak; very young shells are broad oval in outline. Area short, and on the

plane of the edges of the valve; it is divided midway by a narrow pedicle furrow that interrupts the transverse striæ of growth.

Dorsal valve a little shorter and more rounded at the beak; area short and marked by transverse striæ of growth; both valves moderately convex.

The interior of the ventral valve shows what appears to be a short continuation of the cardinal area forward into the valve before the slope into the visceral cavity; it is as though an area with lines of growth was added to the reversed area of the ventral valve of *Elkania desiderata* (Billings) [1862, p. 69]. The front margin of the area merges in *Obolus* (*Fordinia*) *perfectus* into the thicker shell back of the visceral cavity, much as in *Obolus* (*F.*) *bellulus* (Walcott) [1905*a*, p. 323]. The pedicle furrow extends forward from the posterior margin across the true area and its anterior extension to the visceral cavity. The visceral area is bordered by two ridges that diverge from the sides of the pedicle furrow and extend forward about one-third the length of the valve; these ridges widen toward the front, and where they terminate there appear to be two or three minute muscle scars corresponding to the outside and middle laterals and central scars of *Obolus;* outside of the ridge there is a furrow that was probably occupied by the main vascular canal, and, beyond, two narrow elongate spaces in which the transmedian and anterior lateral muscle scars appear to be situated; all the furrows head back against the thickened shell in front of the cardinal area; the surface of the interior of the valve is marked by concentric lines and very fine radiating striæ.

The dorsal valve has a short, strong median ridge in front of the cardinal area, and well toward the center of the valve a narrow, sharp median ridge; on each side of the latter, where it begins posteriorly, the small, oval, central muscle scar occurs, and, at its anterior end, the two elongate, oval anterior-lateral scars that are larger than the centrals; on the thickened postero-lateral portions of the valve the transmedian and outside and middle lateral muscle scars occur close to the outer margin. The surface of the visceral cavity is smooth, but in front of it the minute, irregular vascular markings are very ornate; a few radiating striæ also occur.

The two interiors described are unusually distinct; usually the various parts and scars are more or less obscure.

Observations.—This species approaches *Obolus* (*Fordinia*) *gilberti* (see p. 65) more nearly than any other species of the genus. It differs in the presence of the sinus in both valves; in being less convex; in its less pointed beak, and in its strongly marked interior.

It occurs over 1,000 feet (304.8 m.) higher up in the section of the Middle Cambrian limestones than *O.* (*F.*) *gilberti*. The interior of its ventral valve is somewhat like that of *O.* (*F.*) *bellulus* (Walcott) [1905, p. 323], but it differs from that and all species of *Fordinia* in having in both valves a cardinal area that has not been merged into the reversed area of the ventral valve as in the other species referred to *Fordinia*.

Formation and Locality.—Middle Cambrian: About 3,750 feet (1,143 m.) above the top of the Lower Cambrian and 650 feet (198.1 m.) below the Upper Cambrian, in the shaly limestones of the Weeks formation [Walcott, 1908*a*, p. 10], north side of Weeks Canyon, 3.5 miles (5.63 km.) south of Marjum Pass, House Range, Millard County, Utah.

Subgenus WESTONIA Walcott [1901, p. 683]

OBOLUS (WESTONIA) DARTONI, new species

Plate 7, Figure 14

This species has the general form and convexity of *Obolus* (*Westonia*) *euglyphus* (Walcott) [1898*b*, p. 402], but it differs in the dorsal valve being narrower posteriorly. The surface of the two species differs very much, that of *O.* (*W.*) *dartoni* being of the *O.* (*Westonia*) *ella* (Hall and Whitfield) [1877, p. 232] type and not like that of *O.* (*W.*) *euglyphus*. From *O.* (*W.*) *ella* this species differs in being more elongate in outline and in having the surface more clearly marked by the crossing of the minute ridges; these ridges are slightly irregular and curve from near the umbo obliquely across the shell toward the lateral and front margins. The largest ventral valve has an indicated length of from 12 to 15 mm.; width, 9 mm.

The specific name is given for Mr. N. H. Darton, of the U. S. Geological Survey, who collected the specimens.

Formation and Locality.—Middle Cambrian: Sandstones just above the granite, west of Garfield Peak, 50 miles (80.47 km.) west of Casper, Natrona County, Wyoming.

OBOLUS (WESTONIA) ELLA ONAQUIENSIS, new variety

This variety is represented by a number of more or less imperfect specimens that at first sight might be placed with *Obolus* (*Westonia*) *ella* (Hall and Whitfield) [1877, p. 232], but the character of the surface clearly distinguishes the two forms. In typical forms of *O.* (*W.*) *ella* the transverse striæ are more regular, while in this variety

they are in the form of sharp, finely zigzag, transverse striæ much like the shells from the Big Horn Mountains of Wyoming. This surface is formed by the interruption of very fine, sharp ridges that curve from the umbo outward toward the sides and front of the shell like engine-turning striæ on a watch-case.

Formation and Locality.—Middle Cambrian: Shales about 400 feet (122 m.) above the quartzitic sandstones, from high peak southwest of Lookout Pass, Onaqui Range, west of Vernon, Tooele County, Utah.

OBOLUS (WESTONIA) ELONGATUS, new species

Plate 7, Figure 12

General form elongate oval, with the ventral valve acuminate and the dorsal valve elongate oval. Convexity unknown, as the shells are all flattened by compression.

The outer surface is marked by fine concentric lines of growth crossed by a series of finely denticulated, imbricating lines that start on each cardinal slope and extend obliquely forward across the median line, and then curve out toward the sides of the shell; minute rhomboidal spaces are formed over the posterior and central portions of the shell by the crossing of the oblique lines; the denticulated margin faces forward and is seen only on the thin epidermal layer, while the general system of oblique lines shows on both the outer layer and the next inner layer of the shell.

The shell is built up of several thin layers or lamellæ. The largest specimen of the ventral valve has a length of 9 mm.; width, 5 mm.; a dorsal valve 6 mm. long has a width of 4 mm. Nothing is known of the interior of these valves.

This is a more elongate species than *O.* (*W.*) *bottnica* (Wiman) [1902, p. 51] and *O.* (*W.*) *finlandensis* (Walcott) [1902, p. 611]. The oblique surface lines have the same general direction as those of the latter species, but they are finely denticulated on their front margin and cross at the center at a greater angle.

Formation and Locality.—Middle Ordovician: Gray, siliceous shales just below a band of quartzitic sandstones, probably corresponding in position to the upper part of the Simpson formation of the Oklahoma section; Wasatch Canyon, 5 miles (8.05 km.) north of Brigham, Box Elder County, Utah.

OBOLUS (WESTONIA) NOTCHENSIS, new species

PLATE 7, FIGURE 13

This species is represented by two specimens of the ventral valve that have the general outline of *Lingulella ampla* (Owen) [1852, p. 583]. The exterior surface is marked by concentric lines of growth and transverse, irregular, imbricating lines much like those of *O.* (*W.*) *stoneanus* (Whitfield) [1882, p. 344] and *O.* (*W.*) *iphis* Walcott [1905*a*, p. 336]. The form of the valve differs from that of the latter species.

The largest specimen has a length of 11 mm., with a maximum width of 9 mm.

FORMATION AND LOCALITY.—Lower Ordovician: Thin-bedded, bluish-gray limestone; at the summit of Notch Peak, House Range, Millard County, Utah.

OBOLUS (WESTONIA) WASATCHENSIS, new species

PLATE 8, FIGURES 1 AND 1*a*

This species is founded on some large shells that differ from *Obolus* (*Westonia*) *ella* (Hall and Whitfield) [1877, p. 232] in attaining a larger size and greater proportional width and in having the surface marked by radiating lines that extend from the umbo with a gentle curvature toward the sides and front of the shell, so as to terminate at right angles to the margin, very much as in *O.* (*W.*) *finlandensis* Walcott [1902, p. 611].

In the Blacksmith Fork section of the Middle Cambrian terrane, in the Wasatch Mountains of northern Utah, *O.* (*W.*) *wasatchensis* occurs 1,590 feet (484.6 m.) higher in the section than *O.* (*W.*) *ella*.

FORMATION AND LOCALITY.—Middle Cambrian: (1) Shales about 950 feet (289.6 m.) above the Cambrian quartzitic beds, 2 miles (3.22 km.) southeast of Muskrat Spring, on the northwest face of Grantsville Peak, Stansbury Range, Tooele County; (2) about 1,700 feet (518.2 m.) above the Cambrian quartzitic beds; (3) about 2,300 feet (701 m.) above the Cambrian quartzitic beds; and (4) *a drift block supposed to have come from the horizon of* (2); all three in Wasatch Canyon, east of Lakeview Ranch, 5 miles (8.05 km.) north of Brigham, Box Elder County; (5) about 1,500 feet (457.2 m.) above the Cambrian quartzitic beds, one mile (1.61 km.) northwest of Geneva (Copenhagen), east of Brigham, Box Elder County; (6) about 3,150 feet (960.1 m.) above the top of the Cam-

brian quartzitic sandstones and 1,050 feet (320 m.) below the Upper Cambrian in thin-bedded limestones of the Bloomington formation [Walcott, 1908*a*, p. 7]; and (7) *about 2,100 feet (640.1 m.) above the top of the Cambrian quartzitic sandstones and 2,090 feet (637 m.) below the Upper Cambrian in the shales of the Bloomington formation;* both about 8 miles (12.87 km.) above the mouth of Blacksmith Fork, and 15 miles (24.14 km.) east of Hyrum, Cache County; all in Utah. (8) About 2,000 feet (609.6 m.) above the Cambrian quartzitic beds and 1,200 feet (365.8 m.) below the Upper Cambrian, in the shales of the Bloomington formation, on the south side of Two Mile Canyon near its mouth, 2 miles (3.22 km.) southeast of Malad, Oneida County, Idaho.

MICKWITZELLA, new subgenus of OBOLUS

Obolus (Thysanotos) MICKWITZ, 1896, Mem. Acad. Imp. Sci., St. Pétersbourg, 8th ser., IV, No. 2, pp. 194–195. (Characterized in German as a new subgenus; see below for translation.)

Obolus (Thysanotus) Mickwitz, WALCOTT, 1901, Proc. U. S. National Museum, XXIII, p. 683. (Characterized.)

Not *Thysanota* ALT., 1860.

ORIGINAL DESCRIPTION BY MICKWITZ.—"The subgenus *Thysanotos,* containing a single species, *O. siluricus* Eichwald, differs from the Cambrian subgenera *Euobolus* and *Schmidtia* mainly by the fringed anterior border of the growth lamellæ of its valves and by the concentric striation arranged parallel to the posterior edge of these lamellæ—two features that point to a peculiar organization of the edge of the mantle. The last-mentioned peculiarity appears also in the subgenus *Acritis.*"

TYPE.—*Obolus siluricus* Eichwald [1843, p. 7].

Genus LINGULELLA Salter [1866*b*, p. 333]

LINGULELLA BUTTSI, new species

PLATE 8, FIGURE 6

General form elongate ovate, with the ventral valve bluntly acuminate and the dorsal valve a little more rounded on the posterior margin; both valves rather strongly convex. The greatest convexity of the dorsal valve is at the umbo, and of the ventral valve along the central section. A ventral valve 12 mm. in length has a convexity of 2 mm., and a dorsal valve 8 mm. long arches 1.75 mm. above the plane of the margin. A narrow, median, slightly flattened, almost concave space, that extends from the apex to the front margin, occurs on the dorsal valve. The exterior surface of the shell is dull

dark bluish-gray and the inner layers shiny bluish-black. The outer surface is marked by concentric striæ, and lines of growth with a few indistinct radiating striæ; the striæ on the dorsal valve bend slightly backward where they cross the median, flattened space. The inner layers have many concentric striæ; also numerous fine radiating striæ. The shell is built up of several layers or lamellæ, so as to be strong in the umbonal region and thin toward the edges.

The largest ventral valve in the collection has a length of 12 mm. and a maximum width of 9.5 mm. at the anterior third of its length; a dorsal valve 10 mm. long has a width of 7 mm.

A partially exfoliated ventral valve indicates the presence, on each side of the visceral area, of a strong ridge somewhat similar to that in *Lingulella acutangula* (Roemer) [1849, p. 20].

Observations.—This fine shell has the general outline of the group of small shells of which *Lingulella ferruginea* Salter [Salter and Hicks, 1867, p. 340] is typical. It differs from them in its large size and strong shell. All of the larger species of *Lingulella* are either more acuminate or broader in outline.

The material was collected by Mr. Charles Butts, of the United States Geological Survey, and I take pleasure in naming the species after him.

Formation and Locality.—Upper Cambrian: (1) Limestones in cut on Louisville and Nashville Railroad, near Woodstock; and (2) *limestones near Kimbrel;* both in Bibb County, Alabama.

LINGULELLA TEXANA, new species

Plate 8, Figure 5

This is a small but distinctly marked species, represented by two dorsal valves occurring in the Middle Cambrian limestones of central Texas. The dorsal valves are oval and quite strongly convex. The shell appears to have been rather thick, and the outer surface is marked by strong, radiating striæ, which are characteristic of the species. The striæ are crossed by fine, concentric striæ and lines of growth. The position of the muscle scars and the size and character of the area are shown by fig. 5.

Formation and Locality.—Middle Cambrian: (1) Limestone near Honey Creek; and (2) *limestone near Morgan Creek;* both in Burnet County, Texas. (3) Sandstones of Potosi formation, on Flat River, Missouri.

Subgenus LINGULEPIS Hall [1863, p. 129]

LINGULELLA (LINGULEPIS) ACUMINATA SEQUENS, new variety

PLATE 8, FIGURE 4

Glossina acuminata HALL and CLARKE [not Conrad], 1892, Eleventh Ann. Rept. State Geologist New York for 1891, pl. 1, figs. 10, 11. (No text reference.)

Lingula (*Glossina*) *acuminata* HALL and CLARKE [not (Conrad)], 1892, Nat. Hist. New York, Paleontology, VIII, Pt. 1, pl. 1, figs. 1, 2. (No text reference. Figures 1 and 2 are copied from pl. 1, figs. 10 and 11, of the preceding reference.)

This variety differs from *Lingulella* (*Lingulepis*) *acuminata* (Conrad) [1839, p. 64] in being somewhat less attenuate in its ventral valve and in having the cardinal slope of the ventral valve straight instead of gently incurved. It occurs at a slightly higher geologic horizon than *L.* (*L.*) *acuminata* and appears to be a form derived from that species.

Judging from Messrs. Hall and Clarke's illustrations [1892*a*, pl. 1, figs. 10 and 11], they had representatives of this variety of *L.* (*L.*) *acuminata* and mistook them for the form illustrated by Hall [1847, p. 9] as *Lingula acuminata.* That figure represents a typical form of *L.* (*L.*) *acuminata* and is not the variety illustrated by Hall and Clarke in 1892.

The specimens illustrated by Messrs. Hall and Clarke are given as from the Calciferous sandstone in Saratoga County, New York. The specimen which I have taken as the type of this variety is from Division A of the Beekmantown formation.

FORMATION AND LOCALITY.—Ordovician: Beekmantown formation, Division A; quarry near the northwest suburb of Ticonderoga, Essex County, New York.

NEOBOLUS Waagen [1885, p. 756]

Neobolus WAAGEN, 1885, Mem. Geol. Survey India, Paleontologia Indica, 13th ser., Salt Range Fossils, I, Pt. 4, fas. 5, pp. 756–758. (Described and discussed as a new genus.)

Davidsonella WAAGEN, 1885, idem, pp. 762–764. (Described and discussed as a new genus.)

Not *Davidsonella* MUNIER-CHALMAR, 1880.

Lakhmina OEHLERT, 1887, Manuel de Conchyliologie, by Fischer, p. 1265. (Described in French.)

Lakhmina Oehlert, WAAGEN, 1891, Mem. Geol. Survey India, Paleontologia Indica, 13th ser., Salt Range Fossils, IV, Pt. 2; description of plate II, figs. 3–4. (No text reference.)

Lakhmina Oehlert, HALL and CLARKE, 1892, Eleventh Ann. Rept. State Geologist New York for 1891, pp. 234–235. (Described.)
Neobolus Waagen, HALL and CLARKE, 1892, idem, p. 245. (Described.)
Lakhmina Oehlert, HALL and CLARKE, 1892, Nat. Hist. New York, Paleontology, VIII, Pt. 1, pp. 28–30. (Described and discussed.)
Neobolus Waagen, HALL and CLARKE, 1892, idem, p. 84. (Described and discussed.)

General outline of shells broad oval to subcircular; nearly equivalve, moderately convex. Shell substance calcareo-corneous and probably phosphatic, structure laminated. Surface with concentric striation. Shell strong for its size and built up on its anterior and lateral margins of several thin layers or lamellæ. Apex of ventral valve small and slightly projecting over a low false area that appears to have an open delthyrium. Apex of dorsal valve marginal.

The interior of the ventral valve has a strong rounded central ridge extending from the narrow area about one-third the length of the shell, and a strong ridge on each side that extends from the same point of origin as the central ridge obliquely forward nearly to the frontal margin of the shell.[1] Between the central ridge and the posterior portions of the lateral ridges there are slightly concave shelves forming with the central ridge a triangular platform, with an open space beneath the concave shelves; numerous radiating striæ occur on the concave shelves and the inner surface of the shell.

Of the muscular impressions in the ventral valve, Dr. Waagen wrote [1885, p. 762] that "nothing can be observed." Considered from the point of view of the Trimerellidæ, this may appear to be correct; but if we compare the muscle scars of *Obolus* with what appear to me to be points of attachment of muscles, there is no difficulty in recognizing a few scars. Just beneath the outer extension of the narrow area of the ventral valve there is a minute, clearly defined elongate oval space that corresponds to the divided umbonal muscle scar in *Obolus apollinis* Eichwald [1829, p. 274]. Near the outer margin, on a line with the anterior portion of the central ridge, there is a narrow elongate space which, under a strong reflected light, is seen to be divided diagonally by a slight, narrow, raised line. Compared with *Obolus,* this space is the point of attachment of the transmedian and anterior lateral muscle scars. It is probable that the outside and middle lateral muscle scars and the centrals were attached to the platform, but there are no defined muscle scars upon it.

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[1] I do not find any indication of the incurving of these ridges as described and illustrated by Dr. Waagen [1885, p. 762, pl. LXXXV, fig. 6].

The interior of the dorsal valve has several very unusual characters. There is no true cardinal area, unless the thick margin of the shell be considered as such. From the center of the cardinal margin a strong flat process, marked by concentric lines of growth, projects forward into the valve and rises a little above the plane of the margin of the valve. Dr. Waagen [1885, p. 763] calls attention to the resemblance between this process and the tooth of *Trimerella lindströmi.* From beneath the median process a short thick platform projects upward and forward into the valve; it is as wide as the process at its base, expanding toward its front margin. It is concave between its lateral crests, and the outer slopes are slightly concave from the crest to the body of the shell. In front the concave space and crests terminate rather abruptly above the front face, which in turn is underlain by a transversely hollow space of unknown extension beneath the platform. Toward each end of the frontal area a minute depression appears to indicate the point of attachment of a muscle. A narrow, rounded median septum extends from beneath the platform well toward the front of the shell. Two more or less interrupted and obscure ridges, indicating the main vascular trunks, extend from the front antero-lateral angles at the base of and at the side of the platform obliquely outward into the valve. The elongate smooth spaces outlined by Dr. Waagen [1885, pl. LXXXV, fig. 6] in his illustrations of this valve are too indefinite to be given form in the drawing of the only specimen showing the interior. What appears to be a small muscle scar occurs at the cardinal angle; it corresponds in position to the transmedian scar of *Obolus.*

TYPE.—*Neobolus warthi* Waagen.

OBSERVATIONS.—Through the courtesy of Dr. T. H. Holland, Director of the Geological Survey of India, I received the type specimens of *Neobolus, Davidsonella,* and *Lakhmina,* studied, described, and illustrated by Dr. Waagen. With these before me, I find that the elaborate figures of Waagen [1885, pl. LXXXV] are diagrammatic to a considerable extent; also that I cannot clearly recognize some of the characters noted by Dr. Waagen.

Dr. Waagen's original description [1885, p. 762] of the genus *"Davidsonella"* is very full and he also gives a detailed description of the type species *"D. linguloides."* Dr. Œhlert [1887, p. 1265] evidently based his description of *"Lakhmina"* on Waagen's description and illustrations, apparently not noting that Waagen stated in his text [1885, p. 762] that the elongate areas on the sides of the interior of the shell were not muscle scars, but that he considered them

as smooth areas outside the crescent. Dr. Œhlert [1887, p. 1265] says also that *Lakhmina* has "a straight and projecting beak perforated for the passage of the foramen," and reproduces Dr. Waagen's figures showing a deep pedicle furrow. Only one shell shows the apex of the ventral valve and the small false area beneath, and one other of the interior shows the true area and a triangular depressed spot at the center. A fracture at the center has broken out a bit of the shell, which gives rise to the narrow, deep furrow described by Waagen. The ventral valve has a false area beneath the apex; a true area on a plane with the margins of the valve.

When looking over the types of *Neobolus* and *Lakhmina* for the purpose of having illustrations made of them, I noted that there was a strong resemblance between the shells of the two genera; but, having the impression that the ventral valve of *Lakhmina* had a pedicle opening at the apex, drawings were arranged on the plates under the conception that *Lakhmina* belonged with the Neotremata. Dr. Charles Schuchert noted the same resemblance when looking over the plates of this monograph and called my attention to it. I then made a careful study of all of the specimens, and by the use of acid developed several interiors of dorsal valves. I found that the supposed perforation of the apex of the ventral valve of *Lakhmina* was the result of the breaking out of the minute apex; that the dorsal valve of *Neobolus warthi* was the same as the dorsal valve of *Lakhmina linguloides,* and that two genera and four species had been based on specimens of *Neobolus warthi.*

The external characters of all of the shells referred to *Neobolus* and *Lakhmina* are the same. Only one specimen of the interior of the ventral valve that shows anything of the platform beneath the visceral area occurs in the collections; this was referred to *Lakhmina* by Waagen, but the accompanying dorsal valves were first described as *Neobolus.* By comparing the illustrations of Waagen [1891, pl. II], the student will notice that figure 8*c* of the interior of the dorsal valve of *Neobolus* is essentially the same as the interior of the dorsal valve of *Lakhmina,* figure 4*c,* with the exception of the thickened platform.

It may seem as though it were forcing unlike forms into one species to place all these specimens together, but with our present information it appears to be necessary to do so.

All authors have classified the shells described as *Lakhmina* with *Trimerella linguloides,* and Hall and Clarke [1892*b*, p. 29] state that in the present condition of knowledge it must be regarded as the earliest representative of the Trimerelloid brachiopods. The ex-

ternal form is similar to that of *Obolus* and the interior characters might readily have been developed from that genus.

Genus DICELLOMUS Hall [1873, p. 246]

DICELLOMUS PARVUS, new species

PLATE 8, FIGURES 2 AND *2a*

General form ovate, with the ventral valve subacuminate and dorsal valve broad oval to subcircular. Valves moderately convex. Surface of outer shell dark and polished; it is marked, when not abraded, by fine, clearly defined, concentric striæ and occasional lines of growth. The largest ventral valve has a length of 2.5 mm. and a width of 2 mm. The shell is strong but not thick. Shell substance apparently calcareo-corneous.

Ventral valve uniformly convex, except that the slopes toward the cardinal margins are more abrupt than elsewhere; apex appears to be marginal. The interior of the valve shows a short, low median ridge in the center of the visceral cavity; on each side and a little in front of the end of the median ridge are the trapezoidal areas for the attachment of muscle scars; rather small, composite cardinal muscle scars occur close to the cardinal margins.

Dorsal valve somewhat less convex than the ventral; apex marginal. The interior of the valve shows well-defined composite cardinal muscle scars, a narrow median septum, and a faintly impressed main vascular sinus that curves outward and forward at about one-third the distance from the outer margin to the median septum; the central muscle scars are small and situated back of the center of the valve on each side of a low median swelling on which the median septum occurs; the position of the anterior lateral muscle scars is indicated at the end of the median septum a little in advance of the center of the valve.

OBSERVATIONS.—This minute shell has the generic characters of *Dicellomus politus* (Hall) [1861, p. 24], but it differs specifically in its minute size and in the position of the muscle scars in the dorsal valve.

FORMATION AND LOCALITY.—Middle Cambrian: (1) *Ch'ang-hia limestone, 2.5 miles (4.02 km.) southwest of Yen-chuang, Sin-t'ai District, Shantung, China;* and (2) from a fine-grained bluish-black limestone river drift block one mile (1.61 km.) south of Ch'öng-ping-hien, on the Nan-kiang River, southern Shensi, China.

DICELLOMUS PROLIFICUS, new species

PLATE 8, FIGURES 3 AND 3*a*

This species differs from *Dicellomus politus* (Hall) [1861, p. 24], to which it appears to be most nearly related, by the greater convexity of the ventral valve, its higher umbo, and, in most shells, a greater narrowing toward the apex. The dorsal valve differs from that of *D. politus* in being more rounded on the cardinal margins. It is also to be noted that no traces of muscle scars or vascular markings have been observed on many interiors and casts of the interior of the valves, while in *D. politus* they are prominent on most casts and often on the interior of the valves. The range of outline of the valves of *D. politus* might include those of *D. prolificus,* but the convexity of the ventral valve and the smooth interior seem to distinguish the latter species.

Great numbers of the separated valves occur in several thin layers of gray limestone near the summit of the cliffs on the south side of Marjum Pass.

FORMATION AND LOCALITY.—Middle Cambrian: 2,900 feet (883.9 m.) above the top of the Lower Cambrian and 1,500 feet (457.2 m.) below the Upper Cambrian, in gray, thin-bedded limestone of the Marjum formation [Walcott, 1908*a*, p. 10], south side of Marjum Pass, in cliff southeast of the divide, House Range, Millard County, Utah.

Genus BOTSFORDIA Matthew [1891, p. 148]

BOTSFORDIA ? BARRANDEI, new species

Brachiopode, nouv. gen., DE VERNEUIL and BARRANDE, 1860, Bull. Soc. Geol. France, 2d ser., XVII, pp. 536–537, pl. VIII, figs. 5, 5*a–e*. (Described and discussed in French as a new genus.)

Acrothele POMPECKJ [not Linnarsson], 1896, Jahrb. kais.-könig. geol. Reichsanstalt, Bd. XLV, Heft 3, p. 603. (Discussed in German; see below for translation.)

Of this species Dr. Pompeckj [1896, p. 603] writes:

"From Barrande's description and figure, it is not quite easy to interpret this species. I have before me several specimens of a brachiopod from Coulouma, in the Department of Herault, which Miquel [1893, p. 4] mentioned as *'la Discina.'* I regard this form from southern France as belonging to the genus *Acrothele,* and believe that it is probably identical with the species mentioned by de Verneuil, Barrande, and Barrois as occurring in Spain."

With the specimens collected by M. Miquel before me, and which I have named *Acrothele bergeroni* (see p. 83), I do not think we

can consider them to be the same as the form described by de Verneuil and Barrande [1860, p. 536].

From M. Barrande's description and illustration, the following note is written: The shell is about as wide as long, suboval, with pointed beaks; valves moderately convex, with the ventral a little more so than the dorsal. There is a small area on each valve, but no trace of a triangular false deltidium. Beak of ventral valve with a minute pedicle opening. Surface with fine, distinct, concentric striæ. Substance of shell calcareous.

A shell 13 mm. in length has the same width, and the thickness of the two valves united is 5 mm.

M. Barrande thought that a new genus was indicated, but in the absence of interior characters decided not to name the genus or species. The perforate ventral valve and area suggested *Siphonotreta* to him, but the calcareous shell was opposed to it.

I have provisionally referred the shell to the genus *Botsfordia* and have named it after M. Barrande, whose memory all paleontologists take pleasure in recalling.

The reference to *Botsfordia* is made on account of (*a*) the subacuminate ventral valve with minute pedicle opening above a listrium unmarked by a false deltidium; (*b*) convex ventral and dorsal valve; (*c*) the tendency of *Botsfordia pulchra* (Matthew) [1889, p. 306] to have the substance of its rather thick shell replaced by calcareous matter.

I have attempted to secure specimens of this shell, but unsuccessfully. Until further information can be secured, the present reference will serve to indicate the probable relationship of the species.

Formation and Locality.—Middle Cambrian: Red limestone which passes north of Adrados and Boñar, near Sabero, Cantabrique Range, Province of Leon, Spain.

DEARBORNIA, new genus

This genus is based on one species, which is well represented by fourteen specimens. The generic description is incorporated with the description of the type species.

Type.—*Dearbornia clarki,* new species.

DEARBORNIA CLARKI, new species

Plate 8, Figure 7

Shell subequivalve, subcircular in outline, slightly convex. Ventral valve most elevated at the pedicle aperture, which is circular, rather large, and situated from one-fifth to one-sixth the length of

the valve from the posterior margin; the slope back of the foramen is gently rounded and without a trace of false area or pedicle groove; the position of the beak is not clearly defined, as the margin is rounded and the uniform slope of the outer surface is unbroken. Dorsal valve uniformly and slightly convex; the position of the beak is indicated by a slight projection of the outline of the valve.

Surface marked by fine concentric lines. The substance of the shell is calcareous in an oölitic limestone in which semiphosphatic shells of *Obolus* are preserved. The shell is thick and apparently formed of one layer, but this is probably, as in the case of the shells of *Obolella crassa* (Hall) [1847, p. 290], a condition of preservation, the original layers or lamellæ having been replaced or else cemented together. The average size of the valves is from 3 to 5 mm.

The interior of the ventral valve does not show a true area; there is a space between the margin and the end of the median furrow into which the foramen opens. The median furrow is rather broad and deepest at the foramen; it extends forward beyond the center of the valve; the furrow into which the foramen opens is broadest at the posterior end and running out to a point a little in advance of the opening; from each side of the furrow and opposite the opening a furrow extends obliquely outward and then forward subparallel to the median furrow. Two large, oval muscle scars occur in the space between the outer furrow and the postero-lateral margin of the shell; these scars correspond in position to the transmedian and anterior lateral muscle scars of *Obolus* and *Trematobolus*. Nothing is clearly shown of the position of the main vascular canals unless the grooves outside of the median depression indicate their position, or it may be that they were on the narrow ridges outside of the side furrows and inside of the lateral muscle scars.

The interior of the dorsal valve shows a rudimentary area much like that of *Rustella edsoni* Walcott [1905*a*, p. 311]; the area is a smooth space with a slightly defined central depression, from which a narrow, low median septum extends forward to about the center of the valve; a narrow ridge extends forward from the posterior central depression on each side at about the inner third of the distance between the median septum and the outer margin; these ridges probably marked the position of the main vascular sinuses. The central muscle scars occur in the shallow depression on each side of the median septum a little back of the transverse center of the valve, and the transmedian scars and outside laterals are just outside of the narrow ridges on each side of the valve; these scars, like those in the ventral valve, are large for so small a shell.

OBSERVATIONS.—*Dearbornia clarki* is one of the simple or rudimentary forms of the Siphonotretidæ. It differs from *Siphonotreta* in the absence of an area and a siphonal or pedicle tube, in having the pedicle opening on the umbo in advance of the beak, and in its calcareous shell. The circular pedicle aperture without an exterior furrow, the absence of a well-defined area on the ventral valve, and its calcareous shell distinguish it from *Trematobolus* and *Schizambon.* The form and position of the pedicle opening suggest *Discinopsis,* but the interiors of the valves are very dissimilar in the two genera. It may be that with the discovery of good exteriors of the ventral valve of *Trematobolus excelsis* Walcott (see below) that species will be found to have a circular pedicle opening of the same character as that of *Dearbornia clarki,* but from the similarity of the cast of the interior of the ventral valve of the former species to that of *Trematobolus kempanum* (Matthew) [1897, p. 70] it is referred to *Trematobolus.*

The generic name is taken from Mount Dearborn, which was named after Gen. Henry Dearborn, and the specific name is given in recognition of Dr. William B. Clark's work on the paleontology of Maryland.

FORMATION AND LOCALITY.—Middle Cambrian: Lower portion of the Yogo limestone, in the canyon of the north fork of the Dearborn River, in the eastern part of the Lewis and Clark Forest Reserve, Montana.

Genus TREMATOBOLUS Matthew [1893, p. 276]

TREMATOBOLUS EXCELSIS, new species

PLATE 8, FIGURE 8

Shell transversely oval in outline, with both valves obtusely acuminate. Ventral valve strongly convex, with the minute beak at the posterior margin above a low area; the slope from the highest point of the valve, a little back of the center, is greatest toward the beak and nearly uniform to the front and sides of the valve. Pedicle opening unknown, as no exterior or cast of the exterior of the valve occurs in the material collected; two casts of the interior show the cast of the foramen at about the same position as in *Trematobolus insignis* Matthew [1893, p. 276] and other species of the genus. Dorsal valve slightly more transverse than the ventral and about two-thirds as convex; a very slight median flattening occurs at the anterior margin that extends back on the valve—nearly to the beak in some specimens; otherwise the convexity is distributed as in the ventral valve.

Surface marked by a few concentric lines of growth. The shell is rather thin except over the umbonal and posterior portions of the ventral valve, where it is moderately thick. Its substance is now calcareous and appears like that of *T. insignis;* the original shell may have been calcareo-corneous. A ventral valve 18 mm. in length has the same width; a large dorsal valve 22 mm. long has a width of 27 mm.

The area of the ventral valve is short and divided midway by a depressed subtriangular false pedicle furrow; the presence of pits on each side of the antero-lateral margins of the false pedicle furrow indicates that the area at these places projected in the same manner as that of *T. insignis* and *T. kempanum* (Matthew) [1897, p. 70]. The cast of the interior of the ventral valve shows a median ridge with the cast of the pedicle opening at about the posterior sixth of the length of the valve; only the imperfect outlines of the splanchnocœle are known; the main vascular sinuses are outlined for a short distance back of the transverse center sufficiently to indicate that their position was about the same as in *T. kempanum.* The position of the anterior lateral muscle scar is clearly shown just outside of the main vascular sinuses; it is elongate oval in outline and a little in advance of the transmedian scar; the umbonal muscle scars are close to the median furrow, as in *T. kempanum.* Interior of dorsal valve unknown.

Observations.—This fine species differs from all other known species of the genus in having the ventral valve more convex than the dorsal and in its greater size. It is the oldest species of the genus, occurring as it does well down in the section of the Lower Cambrian strata in association with *Olenellus.* There are a large number of specimens of the exterior of the dorsal valve, but only two interior casts of the ventral valve. The dorsal valves of *T. pristinus* (Matthew) [1895, p. 121] and *T. kempanum* also greatly outnumber the ventral valves in the collections. This circumstance may be owing to the presence of the foraminal furrow and interior median furrows; these would cause the shell of the ventral valve to break more readily than that of the dorsal.

Formation and Locality.—Lower Cambrian: (1) Shales and interbedded limestones at the south end of Deep Spring Valley; (2) shales at a higher horizon than (1), but at the same locality; (3) sandstone on ridge east of the head of Mazouka Canyon, Inyo Range; and (4) *arenaceous limestone one mile (1.61 km.) east of Saline Valley road, 2 to 3 miles (3.22 to 4.83 km.) east-northeast of Waucoba Springs;* all in Inyo County, California.

Genus ACROTHELE Linnarsson [1876, p. 20]

ACROTHELE ARTEMIS, new species

Plate 8, Figure 10

General form of ventral valve moderately convex; subcircular and somewhat obtusely acuminate in outline; apex near the posterior margin; pedicle opening unknown, but from the occurrence of a small boss on the inside of the shell beneath the apex, it was probably of the same character as in closely related species.

Surface marked by concentric lines and small ridges of growth and an irregular system of fine granules on the concentric ridges; in the lower interspaces there is an irregular distribution of very minute inosculating ridges that, with the tubercles, forms a surface independent of the concentric growth lines. The shell is built up of numerous lamellæ beneath the outer surface layer and appears to have been corneous or composed of phosphate of lime and chitin. The largest shell has a length and width of 10 mm.; the apex is about 2 mm. from the posterior margin; dorsal valve unknown.

Observations.—This species resembles in form *Acrothele prima costata* (Matthew) [1895, p. 128], and both species have a granular surface. The latter species, however, has a thinner shell and its surface is marked by much larger granules. I do not know of any other closely related species.

Formation and Locality.—Middle Cambrian: Dark-blue limestones of the Langston formation just above the Cambrian quartzitic sandstone beds on the north side of Two Mile Canyon near its mouth, 2 miles (3.22 km.) southeast of Malad, Oneida County, Idaho.

ACROTHELE BELLAPUNCTATA, new species

Plate 8, Figures 9 and 9′

General form a broad transverse oval, with the posterior side slightly flattened and arched upward for a short distance below the apex. Ventral valve convex near the umbo and nearly flat over the anterior portion of the valve; apex near the posterior margin. Foraminal aperture apparently at the apex above a short, not distinctly marked false area. Ventral valve nearly flat and with the posterior margin curved downward so as to fill the space caused by the upward arching of the margin of the ventral valve. Surface of shell beautifully ornamented by elevated sharp oblique lines with deep interspaces that give a strongly punctate appearance to the

shell; concentric undulations and ridges of growth also occur in a more or less irregular manner. The inner layers or lamellæ are marked by fine, concentric, and rather strong radiating lines. The shell is built up of numerous thin layers or lamellæ of a corneous appearance.

A slightly compressed ventral valve has a length of 5 mm., with a width of 6.5 mm. A ventral valve 4 mm. in length has a width of 5 mm.

This is one of the most beautifully ornamented species of the genus. Its surface is not unlike that of some varieties of *Micromitra* (*Iphidella*) *pannula* (White) [1874, p. 6]. In form it suggests *Acrothele* (*Redlichella*) *granulata* (Linnarsson) [1876, p. 24]. Nothing is known of the interior character of the valves.

FORMATION AND LOCALITY.—Lower Cambrian: Shales in upper portion of *Olenellus kjerulfi* zone, Ringsaker, Province of Hedemarken, Norway.

ACROTHELE BERGERONI, new species

PLATE 8, FIGURE 11

La Discina MIQUEL, 1893, Note Sur la Géologie des Terrains Primaires du Département de l'Herault, St. Chinian à Coulouma, p. 9. (Mentioned in French.)

La Discina MIQUEL, 1894, Bull. Soc. d'Étude Sci. Nat. Beziers, for 1893, Mém. Compte Rendu des Séances, XVI, 1894, p. 106. (This article is a copy of the preceding reference, which was published as a separate.)

La Discina MIQUEL, 1894, Note Sur la Géologie des Terrains Primaires du Département de l'Herault, le Cambrien et l'Arenig, p. 10. (Mentioned in French.)

La Discina MIQUEL, 1895, Bull. Soc. d'Étude Sci. Nat. Beziers for 1894, Mém. Compte Rendu des Séances, XVII, 1895, p. 10. (This article is a copy of the preceding reference, which was published as a separate.)

All the specimens representing this species are flattened by compression in the argillaceous shale; also more or less distorted. A ventral valve 6 mm. in length has the apex 1.5 mm. from the posterior margin. A cast of the interior of a ventral valve indicates a relatively large interior opening for the pedicle tube; a short, small visceral cavity with the shell thickened so as to form a short ridge. and an obscure false area; also that the posterior margin is arched slightly above the plane of the margin of the valve. An exterior cast shows the impression of a minute elongate tubercle on each side of the apex and a small pedicle opening just back of them. A cast of the interior of a dorsal valve shows a short median ridge and the posterior portion of the main vascular sinuses.

The exterior cast shows that the surface was marked by small concentric ridges and lines of growth with a few low, obscure, rounded radiating ridges and fine granulations or tubercles on the very minute, irregular, more or less inosculating concentric ridges, or the same type of surface as that of *Acrothele coriacea* Linnarsson [1876, p. 21]. If these shells were found at the same horizon in Sweden as *A. coriacea,* I think they would be referred to that species, except that the apex of the ventral valve of the French species is much nearer the posterior margin; more perfect specimens would probably show other differences.

This species appears to differ from *Acrothele quadrilineata* Pompeckj [1896, p. 511] and *A. bohemica* (Barrande) [1879, pl. 102, figs. VII: 1-3] by the more anterior position of the apex of the ventral valve.

In response to a request for permission to study the Cambrian brachiopods that he had collected from Montagne Noire, M. Miquel very courteously sent me a number, and among them I found this species, and, with his permission, have described it.

It gives me pleasure to give the specific name in recognition of the discovery by Prof. J. Bergeron of the Middle Cambrian fauna of Herault, and of his fine work on the fauna.

FORMATION AND LOCALITY.—Middle Cambrian: Shales, in Montagne Noire, Coulouma, Department of Herault, France.

ACROTHELE BORGHOLMENSIS, new species

PLATE 8, FIGURE 12

General form subcircular to broad oval. Ventral valve subconical, with the apex a short distance back of the center. A clearly defined false area extends from the apex to the margin; it is defined by a slight depression and a low ridge at the outer edges; two or three longitudinal lines extend to the margin and the concentric lines of growth of the shell cross it without interruption. An elongate, small foraminal aperture occurs just back of and beneath the apex.

The outer surface of the shell is of a dull, dark color and marked by slightly undulating, clearly defined, concentric striæ; the inner layers are marked by fine radiating and concentric lines. The shell is built up of thin lamellæ arranged in concentric layers that are slightly oblique to the surface layer. Shell substance corneous. Nothing is known of the interior of the valves except the sharp median ridge of the dorsal valve.

The largest specimen has a diameter of 4 mm.; the average size is about 3 mm.

Observations.—The material representing this species was collected by M. Schmalensee in the shaly beds of the Ceratopyge zone of Oeland. The convexity, position of the apex, and clearness of the false area depend upon the degree of compression and distortion to which the shells have been subjected. I have described what appears to be the uninjured shell.

The subcentral position of the apex seems to distinguish this species. It is associated with *Obolus* (*Bröggeria*) *salteri* (Holl) [1865, p. 102] and *Lingulella lepis* Salter [1866*b*, p. 334].

Formation and Locality.—Upper Cambrian: Ceratopyge slate at Borgholm, Oeland Island, Sweden.

ACROTHELE LEVISENSIS, new species

Plate 8, Figure 13

Outline transversely broad ovate, ventral valve moderately convex at the apex, which is at about the posterior fifth of the length of the valve; pedicle aperture small and situated on the slope back of and near the apex. Dorsal valve depressed convex, with a very gentle slope from the umbo to the front margin and a greater slope to the marginal beak.

Surface marked by fine concentric lines and striæ that cross the space back of the apex without apparent interruption. A compressed ventral valve 8 mm. in length has a width of 10 mm. A dorsal valve has a length of 7 mm.; width, 8 mm.

The cast of the interior of a compressed dorsal valve shows a median ridge that expands near the center of the valve, and a main vascular sinus on each side that has the same general course as in *Acrothele coriacea* Linnarsson [1876, p. 21].

Observations.—In general form this species is much like *Acrothele coriacea* and related species. It differs from them in having a smooth surface except for the concentric lines and striæ.

The four specimens representing this species were attached to a block in the collections of the Geological Survey of Canada, with specimens of *Elkania desiderata* (Billings) [1862, p. 69].

Formation and Locality.—Lower Ordovician: Levis shales, Point Levis, Province of Quebec, Canada.

ACROTHELE SPURRI, new species

PLATE 8, FIGURE 14

Acrothele subsidua WALCOTT (in part) [not White], 1886, Bull. U. S. Geol. Survey, No. 30, p. 109, pl. IX, fig. 4 (not figs. 4*a–c*). (Locality mentioned in discussion of *A. subsidua.* The specimen represented by fig. 4 is redrawn in this paper, pl. 8, fig. 14.)

Acrothele subsidua WALCOTT (in part) [not White], 1891, Tenth Ann. Rept. U. S. Geol. Survey, p. 608, pl. LXX, fig. 1 (not figs. 1*a–c*). (Mentioned. Fig. 1 is copied from fig. 4 of preceding reference.)

General form transversely ovate. Ventral valve depressed, with an elevated apex a little in front of the posterior margin; from the apex the surface slopes rapidly and then gradually to the front margin and quite rapidly to the posterior margin; the posterior margin arches up from the plane of the sides of the valves about one-half the height of the apex and gives to the valve the appearance of being pushed up so as to throw the apex toward the front; a minute pedicle opening truncates the apex at its posterior side; a small, sub-triangular, convex false area extends from just back of the apex to the posterior margin.

Surface of the epidermal layer marked by fine, concentric striæ of growth and a very minute granulation; the inner laminations of the shell are shiny and marked by numerous radiating striæ and a few concentric lines. Shell corneous and built up of numerous layers or lamellæ more or less oblique to the outer layer.

Dorsal valve and interior of valves unknown. The largest ventral valve has a length of 6 mm.; width, 7 mm.

OBSERVATIONS.—This very striking species is associated with *Acrotreta primæva* Walcott [1902, p. 593] and *Olenellus gilberti* Meek in the upper portion of the Olenellus zone of central Nevada. Some fragmentary specimens of this species were referred by me [1886, p. 109] to *Acrothele subsidua* White [1874, p. 6], but with better material and more thorough study the Lower Cambrian specimens are referred to *A. spurri*. *A spurri* differs from *A subsidua* in the more posterior position of its apex; in its convex, distinctly marked false area; in its strongly arched posterior margin, and in its more finely granulated surface. The convex false area and arched posterior margin are features also seen in *A. woodworthi* (see p. 88) of the Lower Cambrian.

FORMATION AND LOCALITY.—Lower Cambrian: *Associated with Olenellus in the shales and thin interbedded layers of limestone of the Pioche formation* [Walcott, 1908*a*, p. 11], *just above the quartzite on the east side of the anticline near Pioche, Lincoln County, Nevada.*

Doubtfully: Lower Cambrian sandy shales 2.5 miles (4.02 km.) south of Barrel Spring and .5 mile (.80 km.) east of the road, Silver Peak quadrangle (U. S. G. S.), Esmeralda County, Nevada.

ACROTHELE SUBSIDUA HERA, new variety

Plate 8, Figure 15

This variety is separated from *Acrothele subsidua* White [1874, p. 6] by the more elongate outline of the ventral valve, and more posterior position of the apex, the relative position of the latter being between the posterior position of the apex of *Acrothele spurri* (see p. 86) and the more anterior position of the apex of *A. subsidua.* An obscurely defined false area begins at the apical opening and diverges toward the margin. It is marked by a slight median ridge. The exterior layers of the shell are exfoliated, carrying with them the outer portion of the apical opening. The inner portion is rather large, and from the presence of an elongate tubercle on each side it is apparent that there was a similar tubercle on the exterior surface on each side of the apex a little in advance of the opening.

The surface of an interior layer is marked by fine concentric lines, numerous very fine radiating lines, and four sharp ridges that radiate from the apex to the front margin.

Observations.—This species is represented by a single specimen that occurs in the buff-weathering, gray limestone interbedded in a shale carrying fragments of *Olenellus.* It is quite distinct from *A. spurri,* with which it is associated, and appears to be a progenitor of *A. subsidua,* which occurs so abundantly in the Middle Cambrian strata much higher up in the section.

Formation and Locality.—Lower Cambrian: Associated with *Olenellus* in the shales and thin interbedded layers of limestone of the Pioche formation [Walcott, 1908*a*, p. 11], just above the quartzite on east side of anticline, near Pioche, Lincoln County, Nevada.

ACROTHELE TURNERI, new species

Plate 9, Figure 12

General outline broad oval, ventral valve slightly conical, with the apex at about the posterior third of the length of the valve; apex short and perforated on the back side of its point by a minute pedicle opening; false area indicated by a slight flattening between the apex and posterior margin. Dorsal valve gently convex; beak marginal.

Surface marked by fine concentric lines and striæ of growth. Shell corneous and made up of a few very thin lamellæ.

The largest shell has a length of 2.5 mm.; width, 2.75 mm.

Observations.—This neat little shell differs from *Acrothele subsidua* (White) [1874, p. 6] in the absence of the surface characters of that species and from *A. spurri* (see p. 86) by the more anterior position of its beak and smooth surface. It belongs to the group of *Acrothele* represented by *A. borgholmensis* (see p. 84).

Formation and Locality.—Middle Cambrian: *Calcareous shales 10 miles (16.09 km.) south-southeast of Emigrant Peak, Silver Peak quadrangle (U. S. G. S.), Esmeralda County, Nevada.*

Doubtfully: Middle Cambrian shaly limestones about 750 feet (228.6 m.) above the top of the Cambrian quartzitic sandstones and 3,440 feet (1,048.5 m.) below the Upper Cambrian, about 9 miles (14.48 km.) above the mouth of Blacksmith Fork and 16 miles (25.75 km.) east of Hyrum, Cache County, Utah.

ACROTHELE WOODWORTHI, new species

Plate 9, Figure 11

Ventral valve transversely and irregularly oval in outline, convex, with the apex a little back of the center of the valve; pedicle opening, as indicated by the matrix of the exterior, just back of the apex; a subtriangular, gently convex false area is obscurely outlined by lines radiating from the apex to the posterior margin; the posterior margin is arched upward one-third or more of the distance from the plane of the margin of the valve to the apex.

Surface marked by concentric growth lines with fine striæ between, and a number of low, rounded, more or less obscure, radiating ribs. The shell is relatively thick and replaced by the calcareous matter of the matrix.

Observations.—This species is based on two specimens of the ventral valve collected by Prof. J. B. Woodworth. The generic reference is not entirely satisfactory, as the pedicle opening has not been clearly seen and the convex false area suggests the area of *Micromitra* more than that of any *Acrothele* except *A. spurri* (see p. 86).

Formation and Locality.—Lower Cambrian: Nahant limestone, Pulpit Rock, Nahant, Essex County, Massachusetts.

ACROTHELE YORKENSIS, new species

Plate 9, Figure 10

This species is represented in the fine clay shales by casts of the exteriors of the valves and a few imperfect casts of the interior. The shell is large for a species of this genus. Ventral valve mod-

erately convex, with the apex, in a specimen 9 mm. long, 1.5 mm. from the posterior margin. The general outline is subcircular, with the length and width approximately the same. Dorsal valve with the apex marginal. The original convexity of the valves is unknown, as all of the specimens are flattened in the shale.

Surface marked by concentric ridges and striæ of growth and a few obscure, rounded, radiating ridges. In addition, there is a fine granulation of the type of that of *A. coriacea* Linnarsson [1876, p. 21], the irregular, more or less inosculating, minute, rounded ridges having fine tubercles upon them.

A large ventral valve has a length and width of 11 mm. Other specimens of the same size occur, although the average size is about 8 mm. Substance of the shell is unknown.

One or two poor interiors of the ventral valve show a small visceral cavity and rather slender main vascular sinuses that appear to originate beside the pedicle opening. The latter opens on the back slope of the apex and enlarges as it passes through the shell. The interior of the dorsal valve shows a rather strong central ridge that extends beyond the center of the shell; also a rather small cardinal scar on each side of the median ridge close to the posterior margin.

Observations.—This shell is of the general type of *Acrothele matthewi* (Hartt) [1868, p. 644]. It differs in its larger size, and it is not probable that a species would occur in the inner Appalachian trough which is present in the sediments near the margin of the Atlantic basin. The fauna associated with *A. yorkensis* is of the Middle Cambrian type of the interior trough and quite unlike that of the *Paradoxides* fauna of the Atlantic Coast Province. In size this species approaches *A.* (*Redlichella*) *granulata* (Linnarsson) [1876, p. 24], but it differs from that species in its minutely granulated surface.

Formation and Locality.—Middle Cambrian: Argillaceous shales in railroad cut alongside of gas-house, city of York, York County, Pennsylvania.

REDLICHELLA, new subgenus of ACROTHELE

This subgenus of *Acrothele* has all the external characters of the type species of *Acrothele, A. coriacea* Linnarsson [1876, p. 21]. It differs in the interior markings of the valves. The visceral area of the ventral valve is large and clearly defined, as in *Botsfordia granulata* (Redlich) [1899, p. 5], and the main vascular sinuses are very strong and close to the pedicle aperture, as in the latter species. In

the interior of the dorsal valve the cardinal scars are very large and extend forward nearly one-third the length of the valve.

TYPE.—*Acrothele granulata* Linnarsson [1876, p. 24].

I was at first inclined to place this form under *Botsfordia,* but the advanced position of the apex and pedicle opening of the ventral valve indicates a closer affiliation with *Acrothele.* The short listrium of *Botsfordia* has developed in *Redlichella* to the strong false area of *Acrothele,* but the visceral area and main vascular sinuses of *Botsfordia* remain practically unchanged. I regard *Redlichella* as a form intermediate in development between *Botsfordia* and *Acrothele.*

Genus LINNARSSONELLA Walcott [1902, p. 601]

LINNARSSONELLA MODESTA, new species

PLATE 9, FIGURES 8 AND 8*a*

Shell minute; general form subcircular. Ventral valve moderately convex; beak small and slightly incurved over a very low false area; foraminal opening minute exteriorly, with a slightly elevated, sharp ridge on each side a little in advance of the point of the beak; seen from the back, the minute aperture points backward from the bottom of a pit between the two short, sharp ridges. In a specimen from a layer of limestone a short distance above in the section the aperture is at the point of a small nipple-like projection, apparently formed by the union of the ends of the ridges, already described, on each side of the aperture. Dorsal valve slightly convex, with a minute beak at the posterior margin.

Surface dull when the outer layer of the shell is preserved; it is marked by a few very fine, concentric lines of growth. The inner surface is marked by concentric lines and a few fine, radiating lines. The shell is formed of several layers or lamellæ and is relatively thin.

The average diameter of the adult shell is from 1.75 to 2.25 mm.; the dorsal valve is slightly shorter than the ventral.

The cast of the interior of the ventral valve shows a slight longitudinal median elevation and two short, not very strongly marked main vascular sinuses; several specimens indicate a slight cavity just beneath the aperture which probably represents the inner side of the foraminal tube. The interior of a dorsal valve shows main vascular sinuses quite close to the outer margin; also two small, rounded median depressions a short distance in front of the posterior margin.

OBSERVATIONS.—This shell occurs in great abundance on the surface of shaly gray limestone about midway of the strata referred to

the Upper Cambrian in the House Range Section. It differs from *L. nitens* (see below), which occurs a short distance above it in the section, and with which it is also associated, in having a less elevated ventral valve and a less convex dorsal valve, and from *L. transversa* (see p. 92) in being more rounded in outline and less convex. It appears to be more nearly related in form to *L. minuta* (Hall and Whitfield) [1877, p. 206]; it differs, however, materially in the character of the interior markings of the ventral valve, features which also separate it from *L. girtyi* Walcott [1902, p. 602] and *L. tennesseensis* Walcott [1902, p. 604].

FORMATION AND LOCALITY.—Upper Cambrian: 1,160 feet (353.6 m.) above the Middle Cambrian and 2,155 feet (656.8 m.) below the top of the Upper Cambrian, in the arenaceous shales and limestones of the Orr formation [Walcott, 1908*a*, p. 10], 4 miles (6.44 km.) south of Marjum Pass, House Range, Millard County, Utah.

LINNARSSONELLA NITENS, new species

PLATE 9, FIGURE 7

The outline of the valves and the exterior appearance of this shell are much like those of *Linnarssonella modesta* (see p. 90). It differs in having on the ventral valve a low, distinct area, with the perforated apex directed backward on nearly the same plane as the umbo, or most elevated portion of the valve. The dorsal valve is more convex and its interior has a strong median ridge extending forward from the posterior margin about two-thirds of the distance to the front margin, a feature but little developed in *L. modesta*. From *L. minuta* (Hall and Whitfield) [1877, p. 206] it differs in the higher apex of the ventral valve, and from *L. transversa* (see p. 92) in the latter character and in the more circular outline of the aperture of the valves.

A single specimen of *L. modesta* was found associated with this species.

In size *L. nitens* varies from 1.5 to 2 mm. in diameter.

FORMATION AND LOCALITY.—Upper Cambrian: (1) *1,160 feet (353.6 m.) above the Middle Cambrian and 2,155 feet (656.8 m.) below the top of the Upper Cambrian, in the arenaceous shales and limestones of the Orr formation* [Walcott, 1908*a*, p. 10], *4 miles (6.44 km.) south of Marjum Pass, House Range, Millard County, Utah.* (2) About 2,575 feet (784.9 m.) above the top of the Cambrian quartzitic sandstones, in a blue limestone about 2 miles (3.22 km.) southeast of Muskrat Spring, on the northwest face of Grantsville Peak, Stansbury Range, Tooele County, Utah.

LINNARSSONELLA TRANSVERSA, new species

PLATE 9, FIGURE 6

This is a small shell that at first sight suggests *L. modesta;* it differs from that species in the valves being more convex, transverse instead of circular, and in having stronger concentric striæ, and, in some instances, radiating striæ. A few fragments of the interior of the dorsal valve indicate that the main vascular sinuses are well out toward the outer margin, and that small circular depressions occur on each side of the median line, very much as in the dorsal valve of *L. girtyi* (Walcott) [1902, p. 602], and two small central muscle scars midway between the posterior and anterior margins of the valve. *L. transversa* differs from all other species of the genus known by its transverse outline. The average shell has a width of 2 mm., with a length of from 1.5 to 1.75 mm.

FORMATION AND LOCALITY.—Upper Cambrian: At 930 feet (283.5 m.) above the Middle Cambrian and 2,385 feet (726.9 m.) below the top of the Upper Cambrian, in the arenaceous shales and limestones of the Orr formation [Walcott, 1908*a*, p. 10], 4 miles (6.44 km.) south of Marjum Pass, House Range, Millard County, Utah.

LINNARSSONELLA URANIA, new species

PLATE 9, FIGURES 9 AND 9*a*

Shell minute, general form elongate oval. Ventral valve convex; apex minute and curved down nearly to the plane of the margin of the valve; false area, if present, must be very narrow. Foraminal opening situated on the umbo a short distance above the point of the beak; on some shells it opens on the plane of the valve, and on others it has a rounded, slightly elevated margin. Dorsal valve slightly convex, with a minute beak at the posterior margin. Surface of the shell glossy, with very fine concentric striæ and lines of growth. A ventral valve 2.5 mm. in length has a width of 1.75 mm. The dorsal valves are somewhat shorter in proportion to the width.

A partial cast of the interior of the ventral valve shows a small visceral area in front of the foraminal opening. The interior of the dorsal valve is marked by a strong central ridge that extends from the beak four-fifths of the distance to the front margin; on each side of the median ridge, near the posterior margin, there is a rather large, clearly defined cardinal muscle scar.

OBSERVATIONS.—This shell occurs in considerable numbers in a compact, hard, dove-colored limestone 60 to 75 feet (18.3 to 22.9 m.)

above the sandy shales of the Big Cottonwood Canyon Section, Utah. The associated fragments of trilobites indicate the Middle Cambrian fauna of the Wasatch Range Section.

This species differs from *L. girtyi* (Walcott) [1902, p. 602] in not having a false area in the ventral valve and also in the position of the foraminal opening. The incurved apex is more like *L. modesta* (see p. 90), but the form of the ventral valve and the position of the foraminal aperture are quite different.

Formation and Locality.—Middle Cambrian: Limestones about 200 feet (61 m.) above the Cambrian quartzitic beds, about .25 mile (.40 km.) below the Maxfield Mine, Big Cottonwood Canyon, west front of the Wasatch Mountains, southeast of Salt Lake City, Utah.

Genus ACROTRETA Kutorga [1848, p. 275]

ACROTRETA BELLATULA, new species

Plate 9, Figures 4, 4*a*–*b*

General outline subcircular to transversely broad oval, with the posterior margin of the ventral valve nearly straight beneath the false area. The ventral valve is moderately convex, with the apex a little in front of the posterior margin. False area defined by the incurving of the cardinal slopes so as to form a somewhat flattened triangular space that is divided midway by a narrow and rather shallow vertical furrow; pedicle aperture of medium size and opening slightly backward. Dorsal valve nearly as convex as the ventral, except that it curves down in the posterior portion to a minute marginal beak.

Surface of the shell marked by fine, concentric striæ and lines of growth that show marked variations in their sharpness on different specimens, the older shells having a dark, dull surface giving the effect of a thin film over the striæ; a few traces of radiating striæ are shown on some shells.

The average length of the larger shells is about 1.75 mm.; width, 2 mm.

The interior of the ventral valve shows a small apical callosity, minute pedicle tube, and vascular sinuses originating a little back of the apical callosity; a cast shows that there were medium-sized, elevated cardinal muscle scars. An interior cast of the dorsal valve indicates a median ridge that extended about four-fifths of the distance from the area to the front margin. It also indicates medium sized, elevated cardinal muscle scars. A second specimen shows a shorter median ridge, with small, elevated central muscle scars about half way between the posterior and front margins of the shell.

Observations.—This species belongs to the *Acrotreta sagittalis* (Salter) [1866*a*, p. 285] group. The low convexity of the ventral valve, posterior position of the apex, the strong cardinal muscle scars, and the strong median ridge, cardinal and central muscle scars of the dorsal valve are all features common to *Acrotreta bellatula* and *A. sagittalis*. It differs from *A. sagittalis* in the more posterior position of the apex and less convexity of the ventral valve, and from *A. definita* Walcott [1902, p. 584] in its much smaller size and less elevated ventral valve.

Formation and Locality.—Middle Cambrian: 2,825 to 3,025 feet (861.1 to 922 m.) above the top of the Lower Cambrian and 1,400 to 1,600 feet (426.7 to 487.7 m.) below the Upper Cambrian, in the gray thin-bedded limestone of the Marjum formation [Walcott, 1908*a*, p. 10], south side of Marjum Pass, in cliff southeast of the divide, House Range, Millard County, Utah.

ACROTRETA MARJUMENSIS, new species

Plate 9, Figures 2 and 2*a*

The general form of this species is much like that of *Acrotreta idahoensis* Walcott [1902, p. 587]. The ventral valve differs in having a more strongly marked and broader false area and in the greater curvature of the apex over the false area. It is also less elevated, or convex, in proportion to the size of the shell. It may also be compared with *A. neboensis* Walcott [1905*a*, p. 300], from which it differs in being less elevated and in not having a well-indicated false pedicle furrow. The dorsal valve is moderately convex and differs little from the dorsal valve of *A. idahoensis* and *A. neboensis*.

The interior of the dorsal valve shows a narrow median ridge that, at the center and toward the front of the shell, rises as a sharp, rather high, and very narrow ridge. This ridge starts posteriorly from a subtriangular, somewhat elevated area which has a longitudinal furrow crossing it. The cardinal and central muscle scars are very clearly defined; in some cases the central scars are slightly depressed, and in other shells elevated above the general surface of the interior of the shell.

Formation and Locality.—Upper Cambrian: Thin-bedded blue limestone at the base of the high point southwest of the J. J. Thomas ranch, on the east side of the Fish Spring Range, Juab County, Utah.

Middle Cambrian: *About 3,025 feet (922 m.) above the top of the Lower Cambrian and 1,400 feet (426.7 m.) below the Upper Cambrian, in the gray, more or less thin-bedded limestone of Marjum*

formation [Walcott, 1908a, p. 10], south side of Marjum Pass, in cliff southeast of divide, House Range, Millard County, Utah.

ACROTRETA OPHIRENSIS DESCENDENS, new variety

PLATE 9, FIGURES 1 AND 1*a*

In the Cambrian Section of the House Range, Utah, the typical forms of *Acrotreta ophirensis* Walcott [1902, p. 591] occur in the Marjum formation; 1,550 feet (472.4 m.) higher in the section, in the Weeks formation, there are great numbers of a shell identical in many respects. This latter shell differs from the typical form in being less convex in both the ventral and dorsal valves and in having a more pointed, less curved apex on the ventral valve.

FORMATION AND LOCALITY.—Middle Cambrian: About 3,750 feet (1,143 m.) above the top of the Lower Cambrian and 650 feet (198.1 m.) below the Upper Cambrian, in shaly limestones of the Weeks formation [Walcott, 1908*a*, p. 10], north side of Weeks Canyon, 3.5 miles (5.63 km.) south of Marjum Pass, House Range, Millard County, Utah.

ACROTRETA RUDIS, new species

PLATE 9, FIGURE 5

Acrotreta kutorgai WALCOTT (in part), 1902, Proc. U. S. National Museum, XXV, pp. 589–590. (Described as a new species, but the description included specimens belonging to both *A. kutorgai* and *A. rudis*.)

The specimens illustrating this species are all more or less crushed and flattened on the surface of the fine argillaceous shale in which they are embedded in large numbers, and they are often in the condition of casts of the interior of the valves.

The ventral valve, as far as can now be determined, was elevated, conical, and with the apex overhanging the false area, so that when the shells were crushed down the posterior side disappeared beneath. A few fragmentary specimens show the false area to have been distinctly defined, of medium height, and marked by a narrow, shallow median furrow extending from the apex to the margin of the valve. Dorsal valve subcircular, slightly transverse, gently convex, and with a minute beak at the posterior margin. The pedicle opening appears to have been of medium size and situated at the apex of the valve.

Surface marked by lines of growth and very fine concentric striæ that continue across the false area and furrow.

The cast of the interior of the ventral valve shows a small but well defined visceral area in advance of the apex and a short, strong,

main vascular sinus on each side of the area; one cast shows traces of the sinuses nearly to the front margin. The interior of the dorsal valve is marked by a strong median septum or ridge that extends from the front of a small cardinal area forward to nearly the anterior margin in some examples. A large, oval cardinal muscle scar occurs on each side of the median ridge near the posterior border of the valve; the central muscle scars are small, elongate oval, and situated on the sides of the median ridge at about the posterior third of the longitudinal axis of the shell; the two antero-lateral muscle scars are on the sides of the median ridge a little in advance of the central scars.

This is one of the large species of the genus. A dorsal valve 4 mm. in length has a width of 4.5 mm. The ventral valves average from 4 to 4.5 mm. from the apex to the front margin.

In size and outline this species may be compared with *Acrotreta depressa* (Walcott) [1889, p. 441] and *A. definita* Walcott [1902, p. 594]. It differs from both in its ventral valve being more elongate. All the specimens of *A. rudis* are so flattened in the shale that comparison with uncompressed specimens is very difficult.

Formation and Locality.—Middle Cambrian: (1) *Rogersville shale, just above the road, in the hill west of the school-house, 3.5 miles (5.63 km.) from Rogersville, on the road to Melindy's Ferry;* and (2) Rogersville shale, road just east of Harlan's Knob, 4 miles (6.44 km.) northeast of Rogersville; both in Hawkins County, Tennessee.

ACROTRETA ULRICHI, new species

Plate 9, Figure 3

This species is founded on a single specimen of a finely preserved ventral valve. The outline of the aperture is nearly circular, except for a short transverse portion beneath the false area; surface moderately convex, with the apex curving and ending beyond the posterior margin, so that the minute foraminal aperture opens backward; a small false area is indicated by a slight incurving at the cardinal angles; the area is without traces of a median furrow.

Surface of shell marked by very fine, concentric striæ and lines of growth. Length and width of aperture, 2 mm.; convexity of ventral valve, 1 mm.

Observations.—This species is characterized by its curved umbo and apex and overhanging false area. It most nearly resembles *A. curvata* Walcott [1902, p. 584], from which it differs in being less convex and in the form of its umbo and curved apex.

Formation and Locality.—Middle Cambrian: Reagan formation, limestone at northwest extremity of the Arbuckle Mountains, about 4 miles (6.44 km.) east of Homer, Woods County, Oklahoma.

Genus NISUSIA Walcott [1905*a*, p. 247]

NISUSIA RARA, new species

Plate 9, Figures 13 and 13*a*

The ventral valve of this species has the general form of that of *Nisusia festinata* (Billings) [1861*b*, p. 10], except that it has a very strong and deep median sinus and is more transverse; the delthyrium is also larger. *N. rara* occurs at the same stratigraphic horizon as *Nisusia alberta* (Walcott) [1889, p. 442], but it differs from the latter in having a larger delthyrium and a strong and deep median sinus.

The surface of *N. rara* is marked by rounded radiating ribs that increase by interpolation and bifurcation; small nodes on some of the ribs indicate the presence of spines on the outer surface. A portion of a convex deltidium is shown that has the outer portion broken away. The specimen represented by figure 13 has a length of 8 mm.; width, 16 mm.

Formation and Locality.—Middle Cambrian: Spence shale of the Ute formation, about 50 feet (15.2 m.) above the Cambrian quartzitic sandstones and 2,750 feet (838.2 m.) below the Upper Cambrian, in Spence Gulch, a ravine running up into Danish Flat from Mill Canyon, about 6 miles (9.65 km.) west-southwest of Liberty and 15 miles (24.14 km.) west of Montpelier, Bear Lake County, Idaho.

Subgenus JAMESELLA Walcott [1905*a*, p. 252]

NISUSIA ? (JAMESELLA ?) KANABENSIS, new species

This species is represented by a single broken interior cast of a small ventral valve that has a length of 3.5 mm.; width, about 5 mm. The cast is convex, with the base of a prominent extension that filled the interior of the beak. The surface is finely papillose, indicating that the interior surface was finely punctate. The casts of the ribs show them to have been rather sharply rounded and to have increased by bifurcation and interpolation; the absence of all traces of casts of spine bases on the ribs leads me to refer the species to the subgenus *Jamesella*. Area shown only by a narrow rim on one side. The delthyrium was probably quite broad.

The reference of this shell to *Nisusia* is based on the evidence of the presence of a prolonged beak and the character of the ribs. The genus is doubtful, but I do not know of any other to which a tentative reference could be made.

FORMATION AND LOCALITY.—Upper Cambrian: Thin-bedded limestones just below the base of the Ordovician; Lower Kanab Canyon, where it enters the Grand Canyon of the Colorado, Northern Arizona.

NISUSIA (JAMESELLA) LOWI, new species

PLATE 9, FIGURE 14

In form, outline, convexity, and cardinal area of the ventral valve this species resembles *Nisusia festinata* (Billings) [1861*b*, p. 10]. The surface of *N. (Jamesella) lowi* differs from that of *N. festinata* in having more and finer radiating ribs, clearly defined, rounded concentric striæ and lines of growth, and the absence of all traces of the surface spines, so characteristic of *N. festinata*. The latter is also a larger species. *N. (J.) lowi* averages 10 to 12 mm. across the hinge line and rarely over 8 mm. in the length of the ventral valve of the large shells of the species.

The specific name is in honor of Hon. A. P. Low, Deputy Head and Director of the Geological Survey of Canada.

Nisusia (Jamesella) lowi occurs at horizons 186 to 294 feet (56.7 to 89.6 m.) above the horizon of *Nisusia festinata* in the Mount Stephen Section.

FORMATION AND LOCALITY.—Lower Cambrian: (1) *About 5 feet (1.5 m.) below the top of the Lower Cambrian, in thin-bedded limestones of Mount Whyte formation;* (2) drift block of limestone supposed to have come from the horizon of (1); and (3) about 50 feet (15.2 m.) below the top of the Lower Cambrian, in shales of Mount Whyte formation; all three from north shoulder of Mount Stephen, just above the tunnel, on the Canadian Pacific Railway, 3 miles (4.83 km.) east of Field, British Columbia. (4) About 160 feet (48.8 m.) below the top of the Lower Cambrian, in oölitic limestones of Mount Whyte formation, slopes of Mount Bosworth, a little north of the Canadian Pacific Railway track, between Stephen and Hector, British Columbia.

WIMANELLA, new genus

This genus is proposed for the smooth, non-plicate species that I have heretofore referred to the genus *Billingsella*. *Wimanella* represents the smooth, early stages of development and *Billingsella* the

later, mature plicate stage of development of this section of the *Billingsellidæ*.

Type.—*Wimanella simplex,* new species.

It is to be noted that *Billingsella plicatella* Walcott [1905*a,* p. 240] includes some shells that are nearly smooth, and that *B. highlandensis* (Walcott) [1886, p. 119] is very finely costate. The former species may be considered as being in part a form intermediate between *Billingsella coloradoensis* (Shumard) [1860, p. 627] and *Wimanella harlanensis* (Walcott) [1905*a,* p. 236]. I think, however, that the species with smooth shells should be grouped under a generic head, as they indicate a marked phase in the evolution of the forms formerly grouped under *Billingsella.*

The generic name is given in recognition of the valuable work of Dr. Carl Wiman, of the University of Upsala, on the geology and paleontology of the Baltic region.

WIMANELLA ? INYOENSIS, new species

Plate 10, Figure 4

This species is represented by numerous specimens in the form of casts in a calcareous sandstone. All of the shells are more or less compressed and distorted. Some of those best preserved indicate that the general outline was transverse. A specimen 6 mm. in length has a width of 7 mm.

The most striking feature is the presence of two strong radiating ridges that originate near the beak and extend forward nearly to the frontal margin. These ridges may be the casts of the main vascular sinuses or it may be that they represent ridges on the exterior of the shell, one on each side of the shallow median sinus. At present, with the material before me, I am inclined to the view that they represent the casts of sinuses, and hence the provisional generic reference to *Wimanella.*

Nothing is known with certainty of the outer surface or of the substance of the shell. The interior casts and the matrices of the casts show two strong radiating ridges, the shell substance having apparently been removed and its place lost by the compression of the sediment before its consolidation.

Formation and Locality.—Lower Cambrian: Limestones in Toll Gate Canyon, about 15 miles (24.14 km.) east of White Pine, White Mountain Range, Inyo County, California.

WIMANELLA SHELBYENSIS, new species

Plate 10, Figure 3

All the specimens representing this species in the collection are flattened in the shale to such an extent that very little of the original convexity of the shell is left and only the impression of the shell remains, as the shell substance has been entirely removed, probably by solution. The general form of this species resembles very closely that of *Billingsella ? appalachia* (Walcott) [1905, p. 231]. The casts show a high cardinal area on the ventral valve with a broad delthyrium, and on the dorsal valve a narrow cardinal area with a broad, open delthyrium.

The exterior surface is marked by fine concentric lines and a few stronger varices of growth. A small ventral valve has a length of 8 mm., with a width of 10 mm. A larger one has a length of 18 mm.; width, 22 mm. A small dorsal valve has a length of 10 mm.; width, 13 mm.; and the largest dorsal valve in the collection has a length of 19 mm.; width, 25 mm.

The specimens show no traces of vascular or muscular markings, in this respect resembling *Wimanella anomala* (Walcott) [1905*a*, p. 230] and *Billingsella appalachia.*

This species appears to be the Lower Cambrian representative of *Wimanella anomala,* differing from the latter in having rounded cardinal angles instead of the acute projecting angles so characteristic of *W. anomala. Wimanella shelbyensis* has the same general form as *B. appalachia,* but differs from it in having a smooth surface and in the absence of all traces of radiating ribs. It more nearly resembles *Wimanella simplex* (see p. 101), but differs from the latter in being more transverse, and the cast of the umbonal cavity is relatively smaller.

It is a curious fact that in all the species above mentioned there is no trace of a vascular marking or muscle scar. All the species occur in argillaceous shale and none of them preserve the shell substance. The shells appear to have been macerated and removed by solution, leaving only a cast of the compressed inner or outer surface of the valve.

The associated fossils are *Obolus smithi* (see p. 62), *Micromitra (Paterina) major* (Walcott) [1905*a*, p. 304] *Micromitra (Paterina) williardi* (see p. 60) and numerous fragments of two or three species of *Olenellus.*

Formation and Locality.—Lower Cambrian: Montevallo shale, 4 miles (6.44 km.) south of Helena, Shelby County, Alabama.

WIMANELLA SIMPLEX, new species

PLATE 10, FIGURE 2

The general form of this species is much like that of *Billingsella coloradoensis* (Shumard) [1860, p. 627], except that the beak of the ventral valve rises above the hinge line much as in *B. highlandensis* (Walcott) [1886, p. 119]. The surface of *W. simplex* appears to be smooth, except for a few concentric lines of growth. Nothing is known of the interior except what is shown by the cast of the umbonal cavity. A crushed specimen with the two valves flattened out indicates that the beak of the dorsal valve was slightly elevated above the hinge line. All of the specimens are flattened in shale, and the shell substance has been removed by solution. The material is unsatisfactory, but, as it represents a species of the smooth type from a known horizon in the Middle Cambrian, it is illustrated and given a specific name.

FORMATION AND LOCALITY.—Lower Cambrian: (1) *Shales on Gordon Creek north of Gordon Mountain, 6 miles (9.65 km.) above the South Fork of the Flathead River;* and (2) Wolsey shales, below Gordon Mountain, on Youngs Creek, about 5 miles (8.05 km.) from its junction with Danaher Creek; both in the Lewis and Clark Forest Reserve, Montana. (3) Drift block supposed to have come from the Mount Whyte formation, found on the south slope of Mount Bosworth, a short distance northwest of the Canadian Pacific Railway track, between Stephen and Hector, eastern British Columbia, Canada.

Genus BILLINGSELLA Hall and Clarke [1892*b*, p. 230]

BILLINGSELLA MAJOR, new species

PLATE 10, FIGURES 1 AND 1*a*

In general form and convexity this shell is related to *Billingsella coloradoensis* (Shumard) [1860, p. 627]. It differs from it in being larger and in having coarser radiating ribs. It is the Upper Cambrian representative of the latter species.

FORMATION AND LOCALITY.—Upper Cambrian: Fine-grained, buff-colored sandstone in excavation on Wells' farm, 2 miles (3.22 km.) west of Baraboo, Sauk County, Wisconsin.

BILLINGSELLA MARION, new species

PLATE 10, FIGURE 5

Dorsal valve transverse; beak small, marginal; sides broad, rounded, and merging into the broadly round, almost transverse frontal margin; cardinal line a little shorter than the greatest width of the valve and sloping very slightly from the beak to the outer extremities; on one specimen the cardinal angle is extended slightly; greatest width about midway of the length; mesial furrow narrow at the beak and gradually widening to a broad, deep furrow which divides the valve into two lobes.

Surface smooth with the exception of a few (six or seven) obscure radiating ribs on each lobe. A specimen 10 mm. in width has a length of 6 mm.

OBSERVATIONS.—This species is represented by three specimens of the dorsal valve. They all indicate a thick shell of the *Billingsella salemensis* (Walcott) [1887, p. 190] type. I do not know of a similar form in the Cordilleran Cambrian fauna. It is associated with *Micromitra* (*Paterina*) *stissingensis* (Dwight) [1889, p. 145], a species of *Microdiscus,* and *Ptychoparia,* in a compact gray limestone.

FORMATION AND LOCALITY.—Middle Cambrian: About 1,750 feet (533.4 m.) above the top of the Lower Cambrian, in the oölitic limestones of the Stephen formation [Walcott, 1908*a,* p. 3], below the horizon of the *Ogygopsis* fauna, east side of Mount Stephen, about 3,000 feet (914.4 m.) above the Canadian Pacific Railway track and 3.5 miles (5.63 km.) east of Field, British Columbia, Canada.

EOORTHIS, new genus

Not *Plectorthis* HALL and CLARKE, 1892, Nat. Hist. New York, Paleontology, VIII, Pt. 1, pp. 194–195. (Characterized as a new genus; see below for copy. This genus, as now restricted, is not known to occur in the Cambrian.)

Orthis (*Plectorthis*) WALCOTT [not (Hall and Clarke)], 1905, Proc. U. S. National Museum, XXVIII, pp. 257–259. (Original characterization copied and genus discussed somewhat as below.)

Plectorthis GRABAU and SHIMER (in part) [not (Hall and Clarke)], 1907, North American Index Fossils, II, Bryozoa and Brachiopoda, pp. 250 and 251. (Characterized.)

In their subdivision of the genus *Orthis* Dalman, Messrs. Hall and Clarke [1892*b,* p. 192] restricted the genus *Orthis* to the group of which *Orthis callactis* Dalman is the type, and, among American forms, *Orthis tricenaria* of the Trenton and Hudson faunas. These

forms show the existence of a transverse apical plate in the delthyrium of the ventral valve. The name *Plectorthis* was proposed for a second group, of which *Orthis plicatella* was made the type, and of this the authors [1892*b*, p. 194] say:

"This is a persistent form, which in American faunas, so far as known, is limited to the Trenton and Hudson River formations. While it retains the strong external ribs of the typical *Orthis,* these are not invariably simple (*O. fissicosta* Hall; *O. triplicatella* Meek; *O. æquivalvis* Hall, not Davidson; *O. jamesi* Hall), the cardinal area of the pedicle valve is comparatively low and the valves are subequally convex. In the interior, the character of the muscle scars, dental lamellæ and cardinal process are essentially the same as in Group I (*Orthis*), and the minute structure of the shell appears to be in precise agreement with that of *O. calligramma,* though no evidence of tubulose costæ has been observed. In *Orthis jamesi,* which is placed in this association, there is occasionally a deviation toward the resupinate contour exemplified in the Groups IV (*Orthis subquadrata*) and V (*Orthis sinuata*)."

In the Cambrian faunas I find a group of species intermediate between the typical forms of *Billingsella* and of *Orthis,* as limited by Hall and Clarke [1829*b,* p. 193], which I have referred for a long time to Hall and Clarke's *Plectorthis,* placing that genus as a subgenus of *Orthis.* This Cambrian group of shells, which I now refer to a distinct genus, may be defined as follows, the type of the genus being *Orthis remnicha* Winchell [1886, p. 317]:

Diagnosis.—Shells subquadrate to transversely elongate, with or without median fold and sinus; valves subequally convex. Hinge line straight, usually forming nearly the greatest diameter of the shell. Cardinal extremities broadly angular, rarely acuminate; surface with radiating ribs and striæ which may be crossed by concentric growth lines and striæ. The ribs increase as the shell grows, by interpolation.

The ventral valve has the umbo more or less elevated over a hinge line, the apex acute and usually incurved. The area is rather broad, flat or incurved, and transversely striated. Teeth short and supported by dental plates that extend to the bottom of the valve, bounding a space (pseudospondylium) including the main vascular sinuses and area of attachment of the adductor muscle scars. Delthyrium open or partially closed by a convex deltidium. The adductor muscle scars are included within a narrow median area beneath the umbo on each side of the median line, and the diductors in a more or less flabelliform area outside of the main vascular sinuses. Pedicle scars unknown.

Dorsal valve with low umbo and slightly incurved apex; area well developed with a broad delthyrium. Deltidial cavity with a straight, simple cardinal process. Dental sockets small, with short crura. The adductor muscle scars are small, the anterior being nearer the median ridge, which usually extends forward from the base of the cardinal process.

Shell structure dense, with a minutely granular ground-mass. Sections vertical to the outer surface show a few laminations of growth, but no fine fibers; sections on the plane of the surface show a few coarse irregular fibers resembling matted wood-pulp fibers, and a dense granular ground-mass that is penetrated here and there by irregular openings of varying size. The openings or pores appear to be confined to one or more lamellæ of the shell and not to pass through it from inner to outer surface, as in *Orthis* (*Dalmanella*) *parva* and allied punctate orthoids; the openings are usually indicated by minute scattered dark spots.

TYPE OF GENUS.—*Orthis remnicha* Winchell [1886, p. 317].

OBSERVATIONS.—The Cambrian species referred to *Eoorthis* have relatively thin shells that retain on the interior surfaces but slight traces of the muscle scars and vascular markings, except in the umbonal cavity. *Eoorthis* may be distinguished from *Orthis* (s. s.) by (1) its ribs increasing by interpolation; (2) its strongly defined pseudospondylium; (3) relatively thin shell; and (4) its dense, non-fibrous shell structure. The last three characters also distinguish it from *Plectorthis* and other subgenera of *Orthis*. *Eoorthis* may be considered as the possible connecting line between *Billingsella* and the orthoids of the Ordovician.

The geological range of *Eoorthis* is from the upper portion of the Middle Cambrian through the Upper Cambrian and into the Lower portion of the Ordovician.

Two of the species from strata referred to the Middle Cambrian are represented by material too imperfect for specific description; they occur with *Paradoxides* in Bohemia, and it is not improbable that they will be found to belong to some other genus. The remaining species referred to the Middle Cambrian are *E. wichitensis* (Walcott) [1905*a*, p. 271], which occurs in the upper portion of the Middle Cambrian and base of the Upper Cambrian, and *E. hastingsensis* (Walcott) [1905*a*, p. 263], which occurs in the Middle Cambrian (*Paradoxides* zone).

From the above statements it will be seen that the first representatives of *Eoorthis* in the Cambrian appear in the upper portion of the Middle Cambrian, and that the greater number of species, 21 out of 31, are Upper Cambrian forms.

EOORTHIS NEWBERRYI, new species

PLATE 10, FIGURES 6 AND 6*a*

Shell transversely subelliptical, with the cardinal extremities obtusely angular; valves moderately convex, with the hinge line a little shorter than the greatest width of the valves. The only ventral valve in the collection showing a mesial fold is a small exfoliated shell that is somewhat doubtfully referred to the species. Two of the larger valves in the collection have the posterior margin extended beyond the hinge line, with a short incurved beak; a broad, shallow median sinus begins in front of the umbo and widens to nearly one-third of the width of the valve at the frontal margin. On a shell 5 mm. in length the sinus is very shallow; area unknown. The dorsal valve is almost uniformly convex and without a mesial sinus or fold; the front margin arches upward a little to provide for the extension of the margin of the ventral valve caused by its broad median sinus; beak minute and marginal; area unknown.

Surface marked by concentric lines and ridges of growth and small, rounded, radiating ribs with two or three smaller ribs between each two larger ridges. The shell structure is fibrous and impunctate, as far as can be determined from the material available for study. The largest ventral valve has a length of 14 mm.; width, 18 mm. A dorsal valve 15 mm. in length has a width of 18 mm.

OBSERVATIONS.—In form this species resembles some species of *Eoorthis remnicha* (N. H. Winchell) [1886, p. 317], but in surface characters it is quite unlike any of them.

FORMATION AND LOCALITY.—Upper Cambrian: About 1,100 feet (335.3 m.) above the top of the Middle Cambrian and 125 feet (38.1 m.) below the Lower Ordovician, in the limestone of the St. Charles formation of the Blacksmith Fork Section, about 7 miles (11.27 km.) above the mouth of Blacksmith Fork and 14 miles (22.54 km.) east of Hyrum, Cache County, Utah.

EOORTHIS THYONE, new species

PLATE 10, FIGURES 7 AND 7*a*

In outline and size this species resembles *Eoorthis wichitensis* (Walcott) [1905*a*, p. 271], but in its sharp, uniform, radiating ribs it differs from that and other species having a somewhat similar outline. The ribs radiate from the beak and increase in number by interpolation of new ribs at irregular distances from the beak. Nothing is known of the area of either valve. A cast of the interior of a dorsal valve shows rather large muscle scars.

A large ventral valve has a length of 8 mm.; width, 9 mm. Substance of shell unknown.

Observations.—This species was at first compared with *Nisusia* (*Jamesella*) *nautes* (Walcott) [1905*a*, p. 283], but the surface ribs are more regular and less numerous. It also occurs 1,800 feet (548.6 m.) higher in the stratigraphic section than the fauna of *N.* (*J.*) *nautes.*

Formation and Locality.—Middle Cambrian: (1) About 2,250 (685.8 m.) above the top of the Lower Cambrian and 2,150 feet (655.3 m.) below the Upper Cambrian, in the gray shaly limestones of the Marjum formation; and (2) *about 2,450 feet* (*746.8 m.*) *above the top of the Lower Cambrian and 1,950 feet* (*594.4 m.*) *below the Upper Cambrian, in the thin-bedded limestones of the Marjum formation, House Range Section;* both 2.5 miles (4.02 km.) east of Antelope Springs, in ridge surrounding Wheeler Amphitheater, House Range, Millard County, Utah.

EOORTHIS ZENO, new species

Plate 10, Figure 8

In outline the ventral valve of this species is somewhat similar to that of some forms of *Eoorthis remnicha winfieldensis* (Walcott) [1905*a*, p. 270], but it differs in having finer radiating ribs and in its smaller size. It is also much smaller than *Eoorthis newberryi,* and it occurs 4,400 feet lower in the same stratigraphic section. I do not know of any similar form with such regular, fine, sharp, radiating ribs from the Cambrian terrane. The largest ventral valve in the collection has a length of 10 mm.; width, 18 mm.

Formation and Locality.—Middle Cambrian: About 1,100 feet (335.3 m.) above the top of the Lower Cambrian and 3,300 feet (1,005.8 m.) below the Upper Cambrian, in the arenaceous limestone of the Ute formation, in the Blacksmith Fork Section, about 8 miles (12.87 km.) above the mouth of Blacksmith Fork Canyon and 15 miles (24.14 km.) east of Hyrum, Cache County, Utah.

Genus SYNTROPHIA Hall and Clarke [1892*b*, p. 270]

SYNTROPHIA CAMBRIA, new species

Plate 10, Figures 11 and 11*a*

General form transversely oval, strongly convex, but not rotund. Ventral valve moderately convex, with the frontal margin in adult shells prolonged; a flattened median sinus begins on the umbo and widens to two-thirds the width of the shell in front; area unknown.

Dorsal valve moderately convex except on the median fold, which is rounded but not unusually prominent; area unknown.

Surface marked by a few concentric lines of growth. The largest dorsal valve has a length of 8 mm.; width, 11 mm. A ventral valve 9 mm. in length has a width of 14 mm.

Casts of the interior of the valves indicate that there was a low spondylium formed by a short ridge rising a little distance from the center on each side; this separates an area beneath the umbo not unlike that of the ventral valve of *Billingsella*. There is no trace in either valve of a median septum. The spondylium or chamber appears to have been attached to the bottom of the valves or to have had the shell as its bottom; if this view is correct, a true spondylium had not been developed in this species.

OBSERVATIONS.—In form this species is usually most nearly related to *Syntrophia calcifera* (Billings) [1861*a*, p. 318]. It differs in having a less clearly defined beak and less prominent fold on the dorsal valve. There are many points in common between *Syntrophia cambria* and *S. nundina* (Walcott) [1905*a*, p. 292], but they differ in the shorter beak and sharper median fold of the latter. *Syntrophia cambria* occurs in the Wasatch range about 3,300 feet below the base of the Ordovician, while *S. califera* and *S. nundina* occur in the lower Ordovician. It is the oldest species of the genus and is of interest also on account of being closely related in form to the Ordovician species mentioned.

FORMATION AND LOCALITY.—Middle Cambrian: (1) About 1,100 feet (335.3 m.) above the top of the Lower Cambrian and 3,300 feet (1,005.8 m.) below the Upper Cambrian, in the arenaceous limestones of the Ute formation, Blacksmith Fork Section, about 8 miles (12.87 km.) above the mouth of Blacksmith Fork Canyon and 15 miles (24.14 km.) east of Hyrum; and (2) *same horizon as* (1) *and about 10 miles south of that locality, just south of the south fork of East Fork, east of Cache Valley;* both in Cache County, Utah. (3) About 100 feet (30.5 m.) above the Cambrian quartzites, in shales of Tintic Range Section, near summit of ridge between Mammoth and Eureka, Juab County, Utah.

SYNTROPHIA CAMPBELLI, new species

PLATE 10, FIGURES 9, 9*a–c*

General form rotund, unequally biconvex; hinge line short. Ventral valve moderately convex, exclusive of the prolonged frontal margin; it is depressed toward the front in adult shells by a broad median sinus that disappears on the umbo; area short and divided

midway by a relatively large, open, triangular delthyrium. Dorsal valve convex, with an elevated, relatively narrow median fold that does not extend back to the beak; area short and divided by a strong, open, triangular delthyrium.

Surface marked by concentric striæ and a few strong lines of growth. The largest shell is represented by a dorsal valve that has a length of 12 mm.; width, 14 mm. A ventral valve 7 mm. in length has a width of 11 mm.

Casts of the ventral valve show a spondylium supported on a septum that extended from the beak about one-third the distance to the front margin. The spondylium of the dorsal valve rests directly on the interior of the shell without trace of a supporting median septum.

OBSERVATIONS.—The young shells of this species are almost evenly convex, the fold of the dorsal valve and the sinus of the ventral valve of the adult shell not having developed. The characteristic spondylium of each valve is shown in the youngest shells observed. The general form of *Syntrophia campbelli* is much like that of *Syntrophia rotundata* (Walcott) [1905*a*, p. 293], and somewhat like that of *Huenella texana* (Walcott) [1905*a*, p. 294]. It differs from the former in having the spondylium of the dorsal valve resting on the interior of the shell and not supported on a septum, in this respect resembling the spondylium of *H. texana*. Some shells have a somewhat transverse posterior margin like that of *H. texana*, but the larger number have the broadly acuminate outline of *S. rotundata*. The muscle scars of the dorsal valve, as far as known, are similar to those of *Huenella abnormis* (Walcott) [1905*a*, p. 289].

FORMATION AND LOCALITY.—Upper Cambrian: Knox chert, Bunker Hill, Greenville quadrangle (U. S. G. S.), 6 miles (9.65 km.) northeast of Rogersville, Hawkins County, Tennessee.

SYNTROPHIA ? UNXIA, new species

PLATE 10, FIGURE 10

This species is represented by a single specimen of the ventral valve from which the shell has been removed by weathering. The cast of the spondylium shows it to have been of the same type as that of the ventral valve of *Syntrophia primordialis* (Whitfield) [1878, p. 51] and *S. barabuensis* (A. Winchell) [1864, p. 228], and to have been attached to the interior of the valve without any intervening septum. The elongate rounded form and scarcely percept-

ible median sinus serve to distinguish this species from all described forms.

This is the oldest shell of this type known to me. It occurs 5,465 feet (1,665.7 m.) below the summit of the Cambrian, in the House Range Section. I am not fully satisfied with the generic reference, but with the data available it can not well be referred to *Billingsella* or any other known genus of the Cambrian Brachiopoda.

Formation and Locality.—Middle Cambrian: About 2,250 feet (685.8 m.) above the top of the Lower Cambrian and 2,150 feet (655.3 m.) below the Upper Cambrian, in the gray shaly limestones of the Marjum formation, House Range Section, 2.5 miles (4.02 km.) east of Antelope Springs, in ridge surrounding Wheeler Amphitheater, House Range, Millard County, Utah.

HUENELLA, new genus

This genus is proposed to include the more or less plicate species of the Syntrophiidæ that have heretofore been referred by me to the genus *Syntrophia*. They differ from *Syntrophia* in having a more or less radially plicate surface and sessile or pseudo spondylia instead of free spondylia supported by a median septum. With the possible exception of *Huenella etheridgei* (see below), all of the species are from the Upper Cambrian.

The shell structure is fibrous, with many minute pores.

Type.—*Syntrophia texana* Walcott [1905*a*, p. 294].

The generic name is given in recognition of the thorough and valuable work of Dr. F. von Hoyningen-Huene on the "Silurischen Craniaden."

HUENELLA ETHERIDGEI, new species

Plate 10, Figures 13 and 13*a*

Orthis (or *Orthisina*), sp., Etheridge, 1905, Trans. Roy. Soc. South Australia, XXIX, p. 250, pl. xxv, figs. 9 and 10. (Described as below and discussed. The specimens represented by figures 9 and 10 are redrawn in this paper, pl. 10, figs. 13 and 13*a*.)

Dr. Etheridge describes the ventral valve as follows:

"Subquadrilateral, convex, the greatest convexity at about midway in the length of the valve, the sinus gradually deepening and widening toward the front, and bounded laterally by ill-defined folds, one on either side, the surface sloping away on either side rapidly to the lateral margins and at a very much less angle within the sulcus; there are indications of costæ on the divaricating folds and in the sulcus.

"The hinge features are hidden in matrix, nor is the umbo distinctly visible."

The dorsal valve is described as follows:

"Rotundato-quâdrate, the cardinal margin as long as the width of the valve, the surface convex, except on the dorsolateral alations, where it appears to be flattened. There is a central, acute, or pinched-up fold, produced forward, and expanding as it advances. There are indications of the existence of strong, distinct, subradiating costæ.

"Whether or not this is the brachial valve of the species represented by the preceding form, it is, at present, impossible to say; the two occur in the same bed, however."

From the study of the various forms of *Huenella* described herein, I think that the two valves belong to one species, and I take pleasure in naming it after Dr. R. Etheridge, Jr.

FORMATION AND LOCALITY.—Middle (?) Cambrian: Archæocyathinæ white limestone, near Wirrialpa, in the Flinders Range, South Australia.

HUENELLA LESLEYI, new species

PLATE 10, FIGURES 12 AND 12*a*

Only the exterior of the valves of this species is known. In form and outline it is most nearly related to *Huenella texana*. It differs from the latter in being broader in proportion to its length and in having narrow, radiating, rounded ribs over the entire surface.

This is probably the oldest known *Huenella*. *Billingsella coloradoensis* (Shumard) [1860, p. 627] and *Lingulella manticula* (White) [1874, p. 9] occur in the same bed of limestone.

The specific name is given in honor of the late Dr. J. P. Lesley, State geologist of Pennsylvania.

FORMATION AND LOCALITY.—Upper Cambrian: About 200 feet (61 m.) above the Middle Cambrian and 1,025 feet (312.4 m.) below the top of the Upper Cambrian, in the limestones of the St. Charles formation, about 7 miles (11.27 km.) above the mouth of Blacksmith Fork Canyon and 14 miles (22.54 km.) east of Hyrum, Cache County, Utah.

CLARKELLA, new genus

General form rotund, unequally biconvex. Surface smooth or marked by concentric striæ and lines of growth. Ventral valve convex at the umbo and with a strong, broad median sinus; area low and divided by a relatively large delthyrium. Dorsal valve convex at the umbo, which is extended forward into a strong, broad median fold. Cross sections of the valves near the apex and beneath the umbo show a spondylium supported by four or more septa that divide the umbonal cavity into five chambers.

Thin sections of the shell of the type species show it to be fibrous and with many minute pores arranged in lines radiating from the beak to the front and side margins of the valves.

Type.—*Polytoechia ? montanensis* Walcott [1905*a*, p. 295].

This genus is known only by the type species from the Lower Ordovician of Montana. It is distinguished from *Polytoechia* Hall and Clarke [1892*b*, p. 239] by an open delthyrium, smooth surface, and presence of septa and spondylium in the dorsal valve. It differs from *Syntrophia* and *Huenella* in having several septa supporting the spondylia, and also from *Huenella* in having a smooth nonplicate surface.

The generic name is given in recognition of the work of Prof. John M. Clarke, of the Geological Survey of New York, in connection with Prof. James Hall, on the fossil Brachiopoda.

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DESCRIPTION OF PLATE 7

f. = flexure line of area.
h. = central muscle scar.
i. = transmedian muscle scar.
j. = anterior lateral muscle scar.
k. = middle lateral muscle scar.
l. = outside lateral muscle scar.

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Mickwitzia occidens, new species.................................... 54

FIG. 1. View of the type specimen from Lower Cambrian shale, northeast of Silver Peak Mill, Silver Peak quadrangle, Esmeralda County, Nevada, showing the outer and inner surface of the outer layer. U. S. National Museum Catalogue No. 51518.

Mickwitzia pretiosa, new species.................................... 54

FIG. 2. Top view of the type specimen from the Lower Cambrian Eophyton sandstones at Lugnås, Vestergotland, Sweden. U. S. National Museum Catalogue No. 51523.

Micromitra haydeni, new species.................................... 55

FIG. 3. Top view of type specimen of ventral valve. U. S. National Museum Catalogue No. 51437*a*.

3*a*. Posterior view of ventral valve. U. S. National Museum Catalogue No. 51437*b*.

The specimens represented by Figs. 3 and 3*a* are from the Middle Cambrian limestones of the Langston formation in Two Mile Canyon, southeast of Malad, Oneida County, Idaho.

Micromitra (*Iphidella*) *louise*, new species.................................... 56

FIG. 4. Top view of type specimen of ventral valve from the Lower Cambrian shales of the Lake Louise formation, at Lake Louise, south of Laggan, Alberta. U. S. National Museum Catalogue No. 51401*a*.

4*a*. Side view of associated ventral valve. U. S. National Museum Catalogue No. 51401*b*.

Micromitra (*Iphidella*) *nyssa*, new species.................................... 57

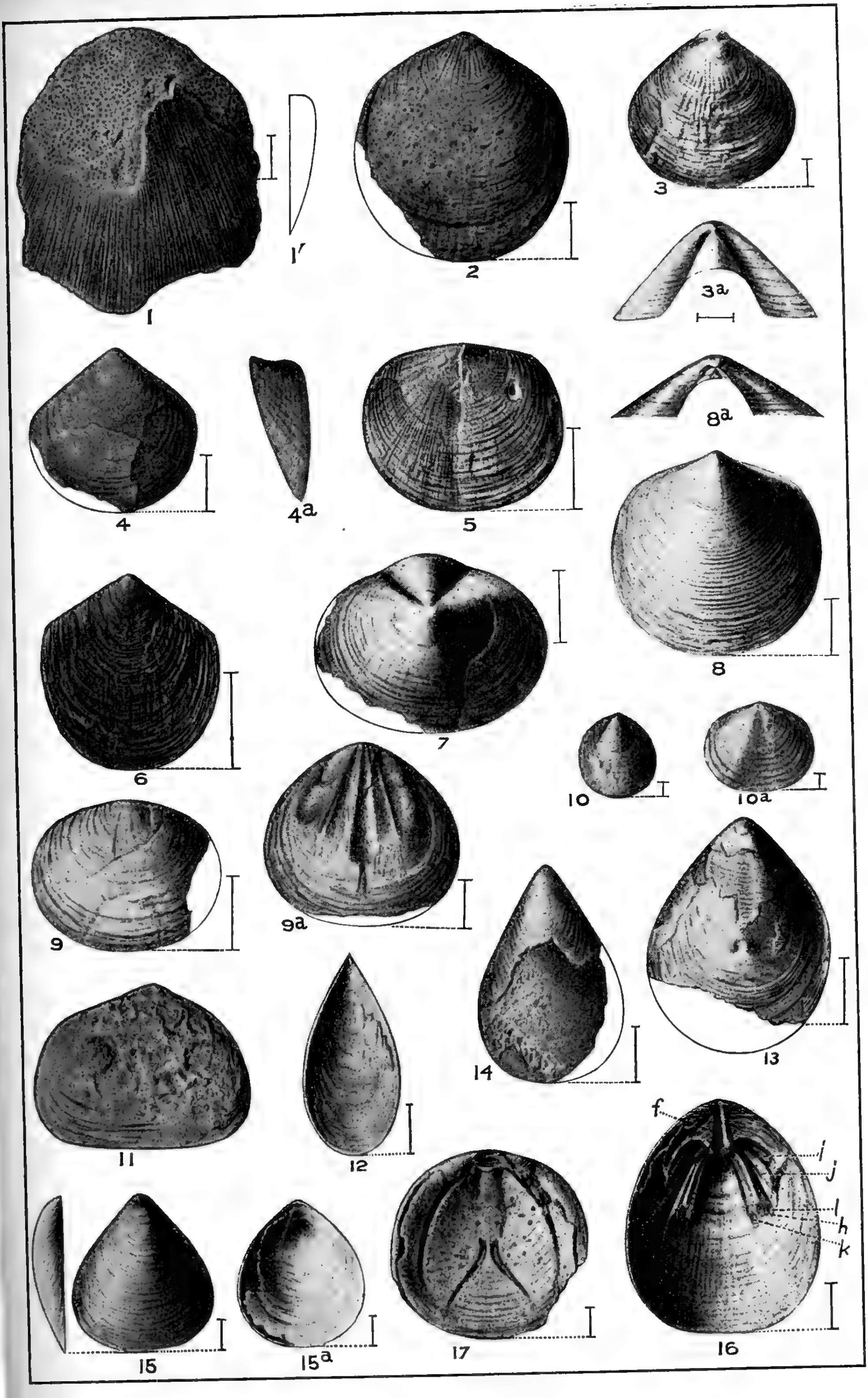
FIG. 5. Top view of type specimen of ventral valve from Middle Cambrian shales between Gordon Mountain and Cardinal Peak, Ovando quadrangle, Powell County, Montana. U. S. National Museum Catalogue No. 51441*a*.

Micromitra (*Paterina*) *wapta*, new species.................................... 59

FIG. 6. Top view of type specimen of ventral valve from a drift block of Lower Cambrian shale, slope of Mt. Bosworth, British Columbia. U. S. National Museum Catalogue No. 51402*a*.

Micromitra (*Paterina*) *williardi*, new species.................................... 60

FIG. 7. Top view of type specimen of ventral valve from the Lower Cambrian Montevallo shale, .25 mile (.40 km.) northeast of Helena, Shelby County, Alabama. U. S. National Museum Catalogue No. 51482*a*.



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Obolus (*Fordinia*) *perfectus*, new species 65

FIG. 16. Type specimen showing interior of ventral valve from Middle Cambrian shaly limestones of the Weeks formation, south of Marjum Pass, House Range, Millard County, Utah. U. S. National Museum Catalogue No. 51947*a*.

Obolus wortheni, new species 63

FIG. 17. Type specimen showing interior of dorsal valve from the Upper Cambrian limestones of the St. Charles formation in Two Mile Canyon, southeast of Malad, Oneida County, Idaho. U. S. National Museum Catalogue No. 51638*a*.

DESCRIPTION OF PLATE 8

Page

a. = area.
cf. = cardinal muscle scar.
F. = foramen.
F'. = cast of foraminal tube.
h. = central muscle scar.
i. = transmedian muscle scar.
j. = anterior lateral muscle scar.
vs. = vascular sinus.

Obolus (*Westonia*) *wasatchensis*, new species........................ 69

FIG. 1. Partially exfoliated ventral valve from a drift block supposed to have come from a Middle Cambrian horizon 1,700 feet (518.2 m.) above the Cambrian quartzitic sandstones, Wasatch Canyon, 5 miles (8.05 km.) north of Brigham, Box Elder County, Utah. U. S. National Museum Catalogue No. 51733.

1*a*. Exterior of a dorsal valve from the Middle Cambrian shales of the Bloomington formation, Blacksmith Fork Canyon, Cache County, Utah. U. S. National Museum Catalogue No. 51734*a*.

Dicellomus parvus, new species.. 76

FIG. 2. Interior of dorsal valve. U. S. National Museum Catalogue No. 52523*a*.

2*a*. Interior of dorsal valve. U. S. National Museum Catalogue No. 52523*b*.

The specimens represented by Figs. 2 and 2*a* are from Middle Cambrian limestones 2.5 miles (40.2 km.) southwest of Yen-chuang, Sin-t'ai District, Shan-tung, China.

Dicellomus prolificus, new species...................................... 77

FIG. 3. Exterior of ventral valve. U. S. National Museum Catalogue No. 51925*a*.

3*a*. Exterior of dorsal valve. U. S. National Museum Catalogue No. 51925*b*.

The specimens represented by Figs. 3 and 3*a* are from Middle Cambrian limestones of the Marjum formation, south of Marjum Pass, House Range, Millard County, Utah.

Lingulella (*Lingulepis*) *acuminata sequens*, new variety... 72

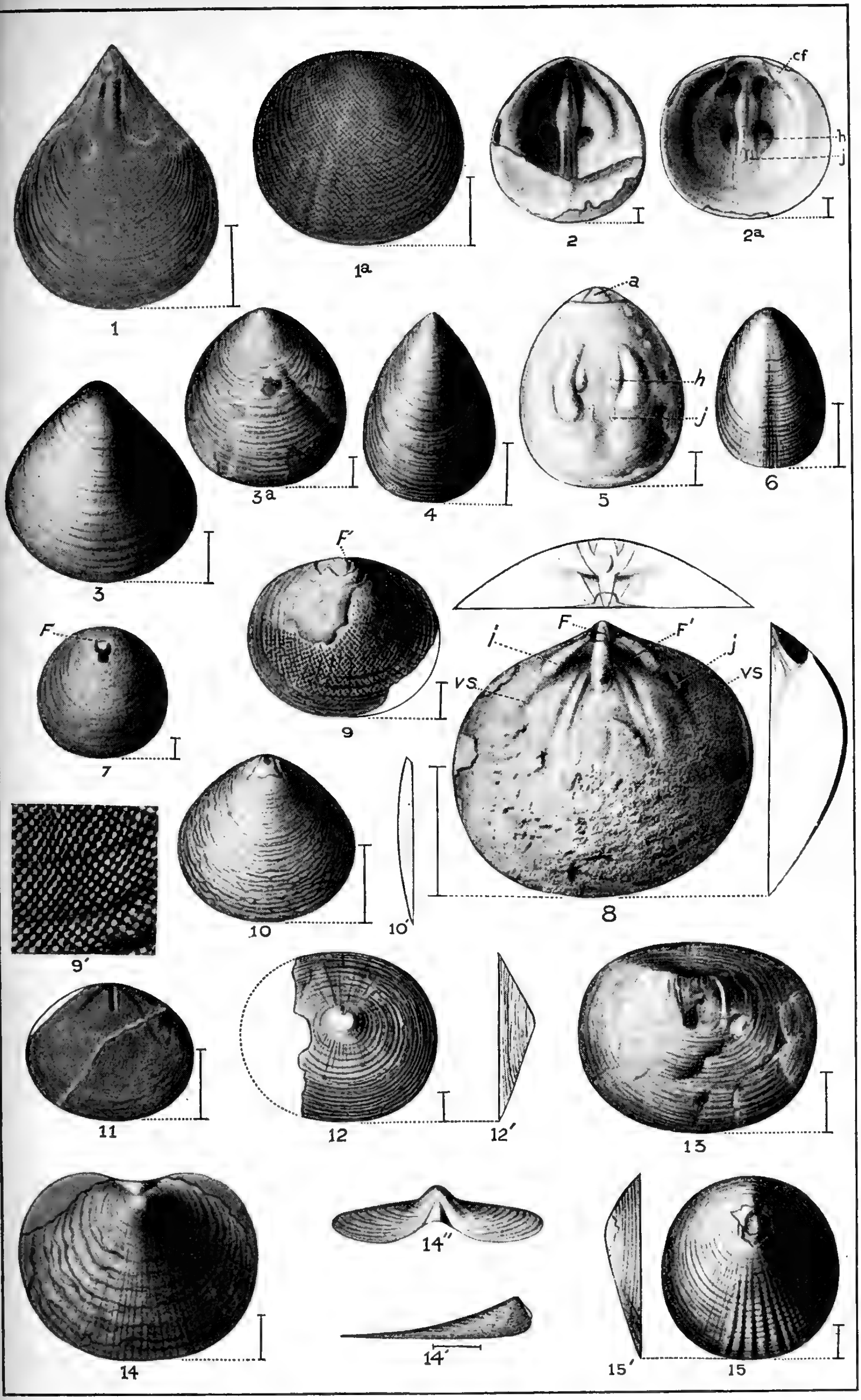
FIG. 4. Exterior of type specimen of ventral valve from Ordovician sandstone, near Ticonderoga, Essex County, New York. U. S. National Museum Catalogue No. 53675*a*.

Lingulella texana, new species.. 71

FIG. 5. Type specimen showing cast of the interior of a dorsal valve from Middle Cambrian limestones on Morgan Creek, Burnet County, Texas. U. S. National Museum Catalogue No. 51806.

Lingulella buttsi, new species.. 70

FIG. 6. Type specimen showing exterior of a dorsal valve from Upper Cambrian limestones, near Kimbrel, Bibb County, Alabama. U. S. National Museum Catalogue No. 51779.



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DESCRIPTION OF PLATE 9

Page

ac. = apical callosity.
cl. = cardinal muscle scars.
fp. = pseudo pedicle groove.
h. = central muscle scars.
s. = median septum.
vs. = vascular sinuses.

Acrotreta ophirensis descendens, new variety........................... 95

FIG. 1. Top, side, and back views of type specimen of ventral valve from Middle Cambrian shaly limestones of the Weeks formation, south of Marjum Pass, House Range, Millard County, Utah. U. S. National Museum Catalogue No. 52143*a*.

1*a*. Interior of an associated dorsal valve. U. S. National Museum Catalogue No. 52143*b*.

Acrotreta marjumensis, new species................................. 94

FIG. 2. Top, side, and back views of a ventral valve. U. S. National Museum Catalogue No. 52116*a*.

2*a*. Interior of an associated dorsal valve. U. S. National Museum Catalogue No. 52116*b*.

The specimens represented by Figs. 2 and 2*a* are from the Middle Cambrian limestones of the Marjum formation, south of Marjum Pass, House Range, Utah.

Acrotreta ulrichi, new species.. 96

FIG. 3. Top, back, and side views of type specimen of ventral valve from the Middle Cambrian limestones of the Reagan formation, east of Homer, Woods County, Oklahoma. U. S. National Museum Catalogue No. 52180.

Acrotreta bellatula, new species...................................... 93

FIG. 4. Top, side, and back views of a ventral valve. U. S. National Museum Catalogue No. 52072*a*.

4*a*. Interior of a ventral valve. U. S. National Museum Catalogue No. 52072*b*.

4*b*. Cast of the interior of a dorsal valve. U. S. National Museum Catalogue No. 52072*c*.

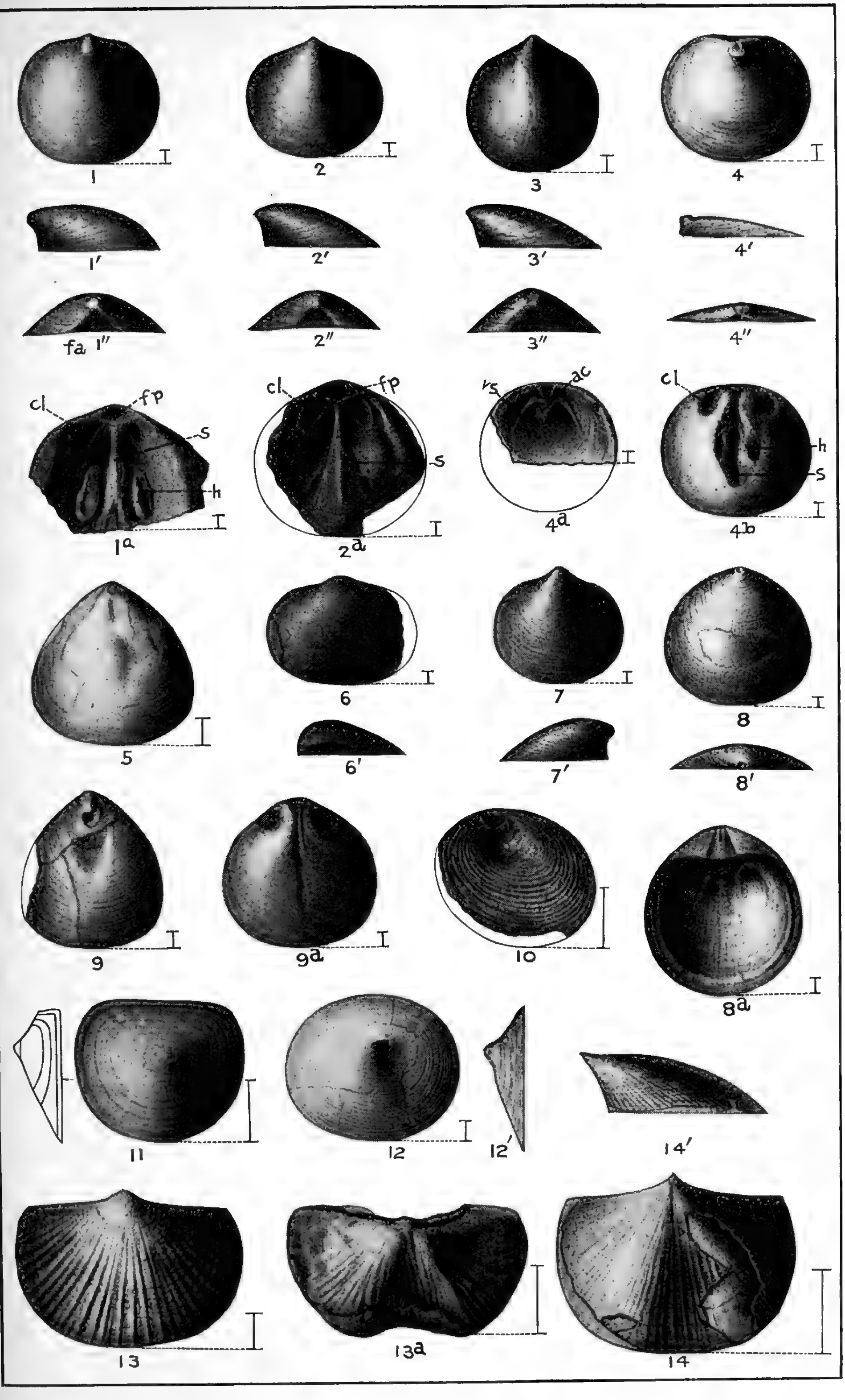
The specimens represented by Figs. 4, 4*a–b* are from Middle Cambrian limestones of the Marjum formation, south of Marjum Pass, House Range, Millard County, Utah.

Acrotreta rudis, new species.. 95

FIG. 5. Type specimen, an exfoliated and crushed ventral valve from Middle Cambrian shales, 3.5 miles (5.63 km.) from Rogersville, on the road to Melindy's Ferry, Hawkins County, Tennessee. U. S. National Museum Catalogue No. 52111.

Linnarssonella transversa, new species............................... 92

FIG. 6. Top and side views of type specimen of ventral valve from Upper Cambrian shales of the Orr formation, south of Marjum Pass, House Range, Millard County, Utah. U. S. National Museum Catalogue No. 52201.



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Linnarssonella nitens, new species.................................... 91

FIG. 7. Top and side views of type specimen of ventral valve from Upper Cambrian limestones of the Orr formation, south of Marjum Pass, House Range, Millard County, Utah. U. S. National Museum Catalogue No. 52198*a*.

Linnarssonella modesta, new species.................................... 90

FIG. 8. Top and back view of a ventral valve. U. S. National Museum Catalogue No. 53679.

8*a*. Interior of a ventral valve. U. S. National Museum Catalogue No. 52197*a*.

The specimens represented by Figs. 8 and 8*a* are from Upper Cambrian shales of the Orr formation, south of Marjum Pass, House Range, Millard County, Utah.

Linnarssonella urania, new species.................................... 92

FIG. 9. Exterior of a ventral valve. U. S. National Museum Catalogue No. 52202*a*.

9*a*. Cast of the interior of a dorsal valve. U. S. National Museum Catalogue No. 52202*b*.

The specimens represented by 9 and 9*a* are from Middle Cambrian limestones in Big Cottonwood Canyon, southeast of Salt Lake City, Utah.

Acrothele yorkensis, new species.................................... 88

FIG. 10. Type specimen showing exterior of a crushed ventral valve from Middle Cambrian shales at York, York County, Pennsylvania. U. S. National Museum Catalogue No. 52031*a*.

Acrothele woodworthi, new species.................................... 88

FIG. 11. Top view and side outline of a cast of the type specimen of a ventral valve from the Lower Cambrian Nahant limestone, at Nahant, Essex County, Massachusetts. U. S. National Museum Catalogue No. 52030 (cast).

Acrothele turneri, new species.................................... 87

FIG. 12. Top and side views of type specimen of ventral valve from Middle Cambrian shales south of Emigrant Peak, Esmeralda County, Nevada. U. S. National Museum Catalogue No. 52028*a*.

Nisusia rara, new species.................................... 97

FIG. 13. Exterior of a ventral valve. U. S. National Museum Catalogue No. 52295*a*.

13*a*. Cast of the interior of a dorsal valve. U. S. National Museum Catalogue No. 52295*b*.

The specimens represented by Figs. 13 and 13*a* are from the Middle Cambrian Spence shales in Spence Gulch, west of Montpelier, Bear Lake County, Idaho.

Nisusia (Jamesella) lowi, new species.................................... 98

FIG. 14. Top and side views of type specimen of ventral valve from Lower Cambrian limestones 5 feet (1.5 m.) below the top of the Mt. Whyte formation, just above the tunnel, north shoulder of Mt. Stephen, 3 miles (4.83 km.) east of Field, British Columbia. U. S. National Museum Catalogue No. 53677*a*.

DESCRIPTION OF PLATE 10

Page

a. = cardinal area.
a'. = cast of umbonal cavity.

Billingsella major, new species.. 101

FIG. 1. Cast of the interior of a broken ventral valve. U. S. National Museum Catalogue No. 52256*a*.

1*a*. Cast of a dorsal valve. U. S. National Museum Catalogue No. 52256*b*.

The specimens represented by Figs. 1 and 1*a* are from Upper Cambrian sandstones 2 miles (3.22 km.) west of Baraboo, Sauk County, Wisconsin.

Wimanella simplex, new species.. 101

FIG. 2. Type specimen showing exterior of ventral valve from Lower Cambrian shales, 6 miles (9.66 km.) up Gordon Creek from South Fork of Flathead River, Lewis and Clark Forest Reserve, Montana. U. S. National Museum Catalogue No. 52278*a*.

Wimanella shelbyensis, new species.. 100

FIG. 3. Type specimen showing exterior of compressed ventral valve from Lower Cambrian Montevallo shale, 4 miles (6.44 km.) south of Helena, Shelby County, Alabama. U. S. National Museum Catalogue No. 52272*a*.

Wimanella ? inyoensis, new species.. 102

FIG. 4. Type specimen showing cast of the interior of ventral valve from Lower Cambrian limestone in Toll Gate Canyon, White Mountain Range, Inyo County, California. U. S. National Museum Catalogue No. 52255*a*.

Billingsella marion, new species.. 99

FIG. 5. Type specimen showing cast of the interior of ventral valve from Middle Cambrian limestones of Stephen formation on Mount Stephen, British Columbia. U. S. National Museum Catalogue No. 53676*a*.

Eoorthis newberryi, new species.. 105

FIG. 6. Exterior of ventral valve. U. S. National Museum Catalogue No. 52350*a*.

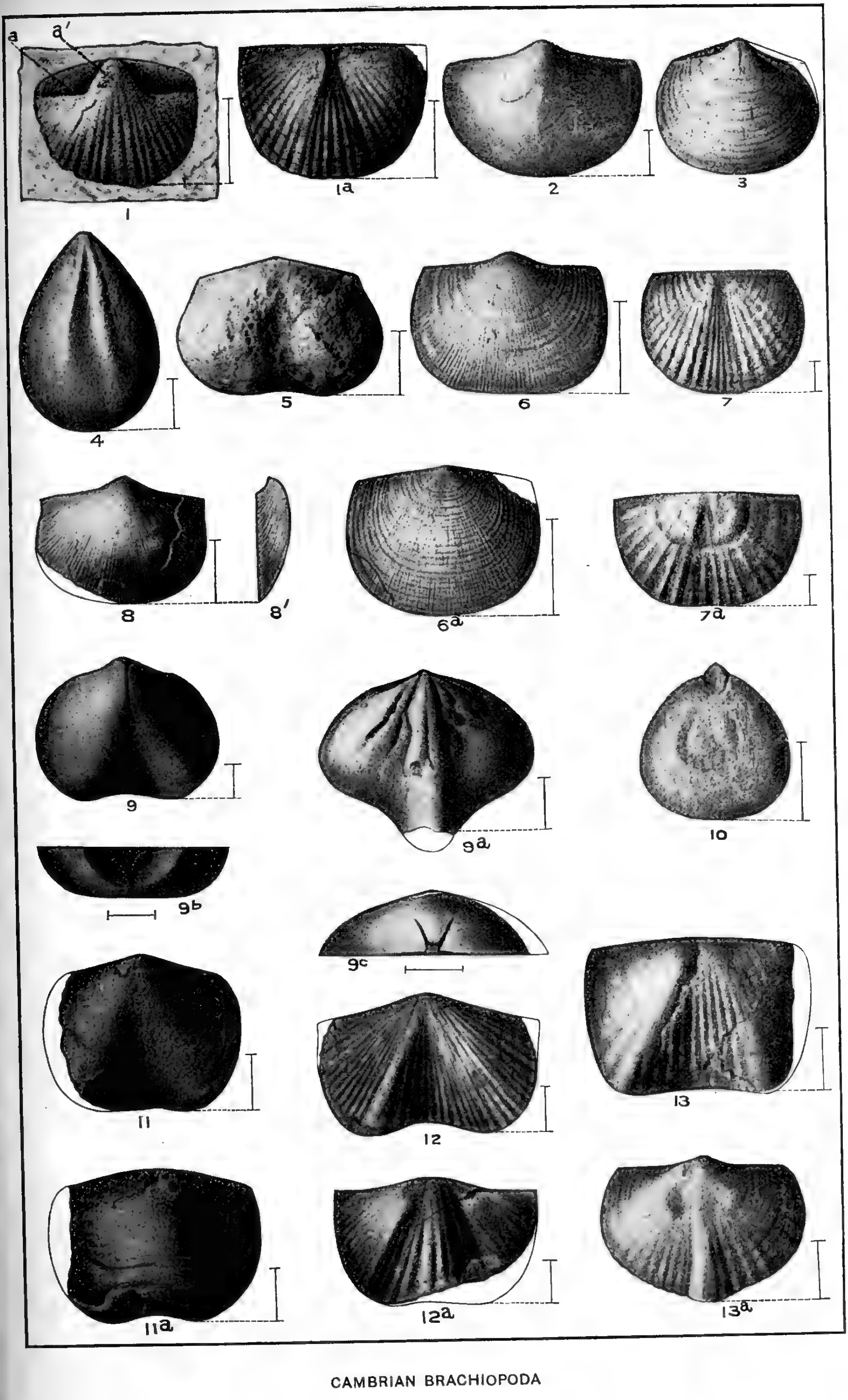
6*a*. Exterior of dorsal valve. U. S. National Museum Catalogue No. 52350*b*.

The specimens represented by Figs. 6 and 6*a* are from Upper Cambrian limestones of the St. Charles formation, in Blacksmith Fork Canyon, east of Hyrum, Cache County, Utah.

Eoorthis thyone, new species.. 105

FIGS. 7 and 7*a*. Exterior of dorsal valves. U. S. National Museum Catalogue Nos. 52377*a* and 52377*b*.

The specimens represented by Figs. 7 and 7*a* are from Middle Cambrian limestones of the Marjum formation, east of Antelope Springs, House Range, Millard County, Utah.



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Eoorthis zeno, new species.. 106

FIG. 8. Exterior view and side outline of type specimen of ventral valve from Middle Cambrian limestones of the Ute formation, in Blacksmith Fork Canyon, east of Hyrum, Cache County, Utah. U. S. National Museum Catalogue No. 52397*a*.

Syntrophia campbelli, new species.. 107

FIG. 9. Cast of interior of ventral valve. U. S. National Museum Catalogue No. 52480*a*.

9*a*. Cast of the interior of a dorsal valve. U. S. National Museum Catalogue No. 52480*b*.

9*b*. Section of the beak of a ventral valve, showing septum and spondylium. U. S. National Museum Catalogue No. 52480*c*.

9*c*. Cast of the interior of the posterior portion of the dorsal valve, showing the cast of a section of the spondylium. U. S. National Museum Catalogue No. 52480*d*.

The specimens represented by Figs. 9, 9*a-c* are from the Upper Cambrian Knox chert at Bunker Hill, northeast of Rogersville, Tennessee.

Syntrophia ? unxia, new species.. 108

FIG. 10. Type specimen showing an imperfect cast of the interior of a ventral valve from Middle Cambrian shaly limestones of the Marjum formation, east of Antelope Springs, House Range, Millard County, Utah. U. S. National Museum Catalogue No. 52499.

Syntrophia cambria, new species.. 106

FIG. 11. Exterior of ventral valve. U. S. National Museum Catalogue No. 52477*a*.

11*a*. Exterior of dorsal valve. U. S. National Museum Catalogue No. 52478.

The specimens represented by Figs. 11 and 11*a* are from Middle Cambrian limestones of the Ute formation in East Fork Canyon, east of Cache Valley, Utah.

Huenella lesleyi, new species.. 110

FIG. 12. Exterior of ventral valve. U. S. National Museum Catalogue No. 52481*a*.

12*a*. Exterior of dorsal valve. U. S. National Museum Catalogue No. 52481*b*.

The specimens represented by Figs. 12 and 12*a* are from Upper Cambrian limestones of the St. Charles formation in Blacksmith Fork Canyon, east of Hyrum, Cache County, Utah.

Huenella etheridgei, new species.. 109

FIG. 13. Partial cast of interior of ventral valve.

13*a*. Partial cast of interior of dorsal valve.

The specimens represented by Figs. 13 and 13*a* are from Middle Cambrian limestones near Wirrialpa, in the Flinders Range, South Australia. Collections of the University of Adelaide, South Australia. Casts in U. S. National Museum, Catalogue Nos. 53678*a* and 53678*b*.

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[1] Brackets are used in this connection to indicate that while the author, whose name is thus bracketed, described a fossil under the name which precedes his own, he was not the first to describe a fossil under that name.

[2] The number in heavy-faced type refers to the page upon which the species is described.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
PART OF VOLUME LIII

CAMBRIAN GEOLOGY AND PALEONTOLOGY

No. 4.—CLASSIFICATION AND TERMINOLOGY OF THE CAMBRIAN BRACHIOPODA

WITH TWO PLATES

BY
CHARLES D. WALCOTT

No. 1811

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
OCTOBER 13, 1908]

CAMBRIAN GEOLOGY AND PALEONTOLOGY

No. 4.—CLASSIFICATION AND TERMINOLOGY OF THE CAMBRIAN BRACHIOPODA[1]

By CHARLES D. WALCOTT

(With Two Plates)

CONTENTS

INTRODUCTION

My study of the Cambrian Brachiopoda has advanced so far that it is decided to publish, in advance of the monograph,[2] a brief outline of the classification, accompanied by (*a*) a schematic diagram of evolution and scheme of classification; (*b*) a note, with a diagram, on the development in Cambrian time; (*c*) a note on the structural characters of the shell, as this profoundly affects the classification; and (*d*) a section on the terminology used in the monograph. The monograph, illustrated by 104 quarto plates and numerous text figures, should be ready for distribution in the year 1909.

SCHEMATIC DIAGRAM OF EVOLUTION

In order to formulate, as far as possible, in a graphic manner a conception of the evolution and lines of descent of the Cambrian Brachiopoda, a schematic diagram (see plate 11) has been prepared for reference. It is necessarily tentative and incomplete, but it will serve to point out my present conceptions of the lines of evolution of the various genera, and it shows clearly the very rapid development of the primitive Atrematous genera in early Cambrian time.

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[1] Published by permission of the Director of the U. S. Geological Survey.

[2] Monograph LI, U. S. Geological Survey.

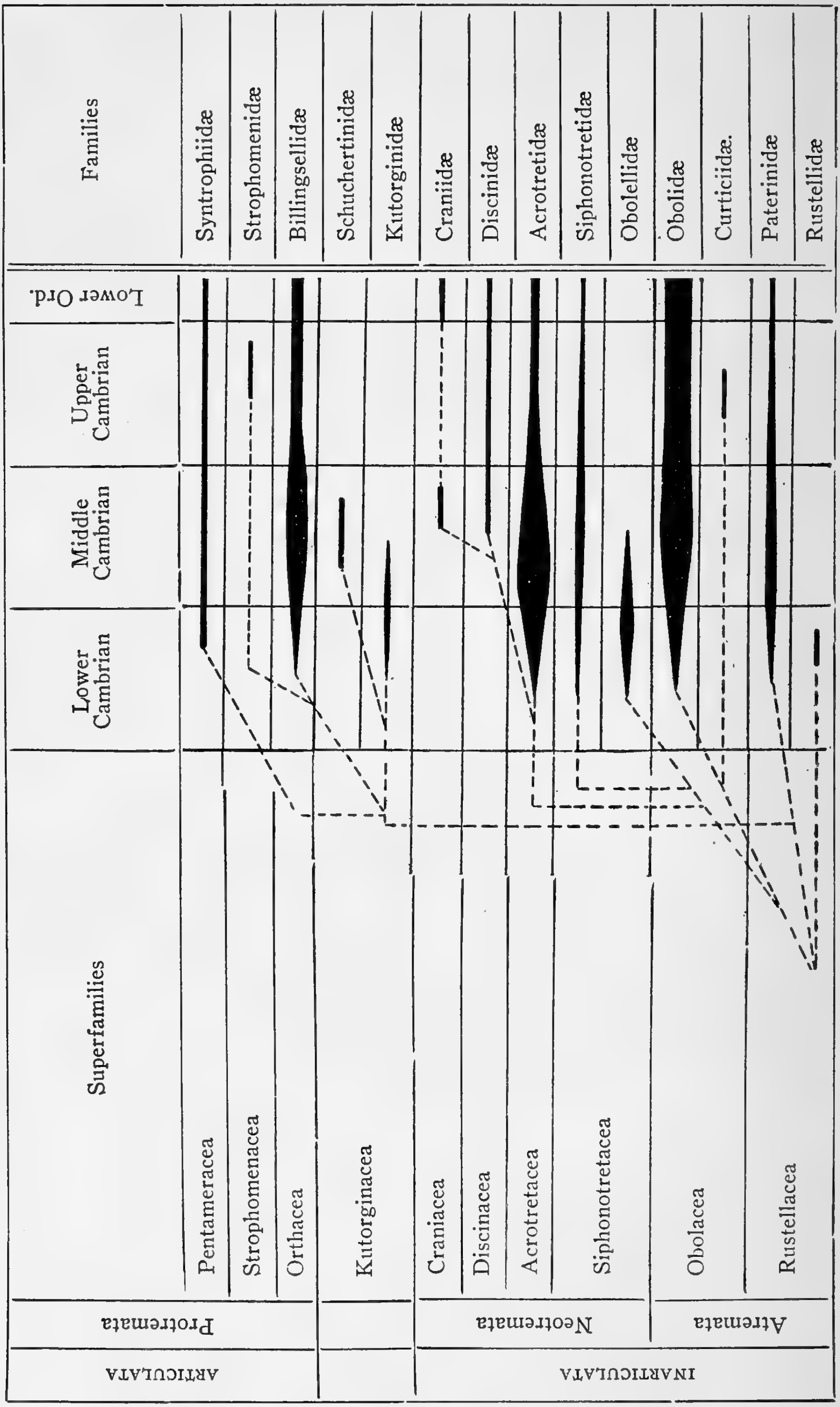
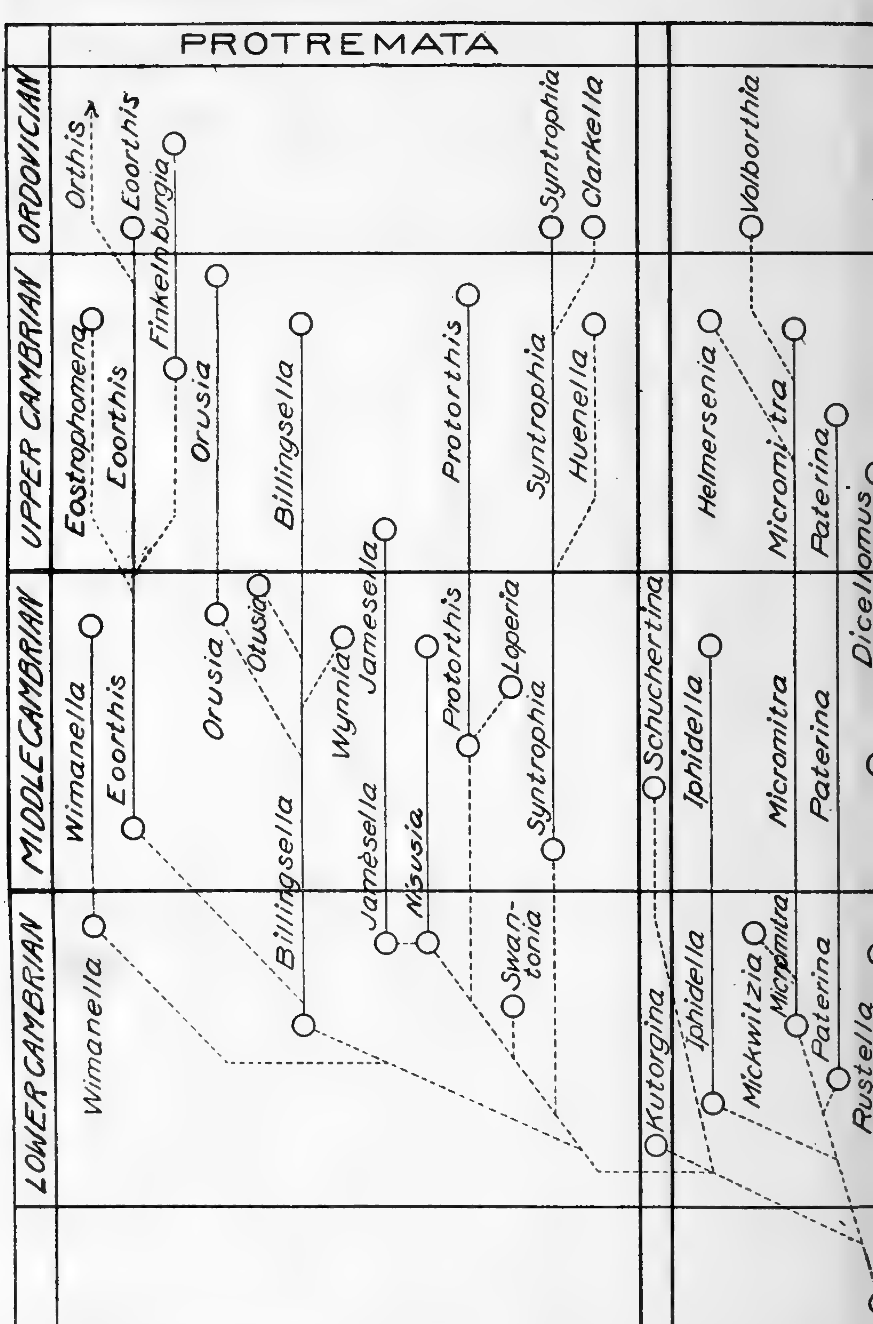


FIG. 1.—Diagram Illustrating Known Distribution of Families in Cambrian Strata.



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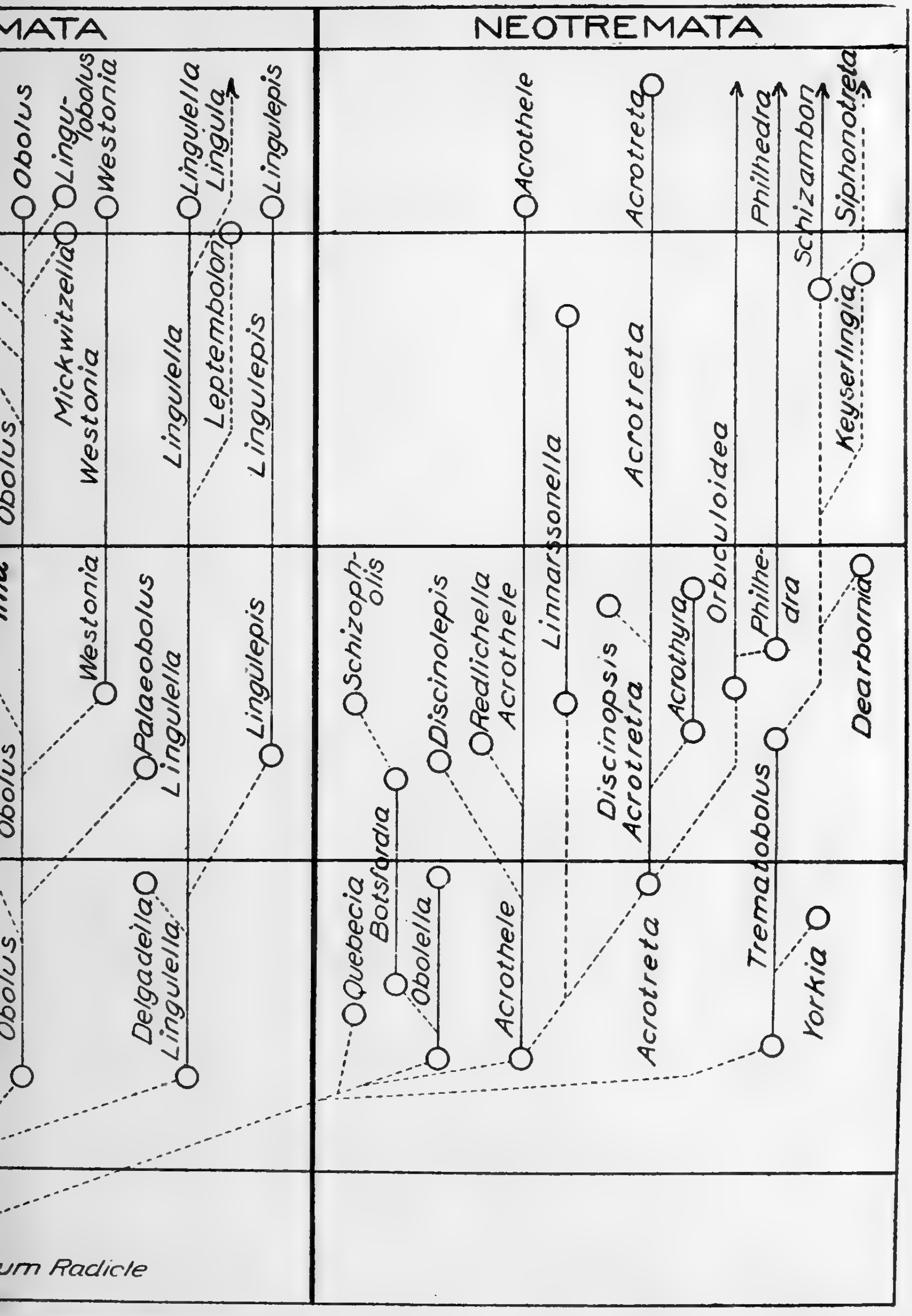
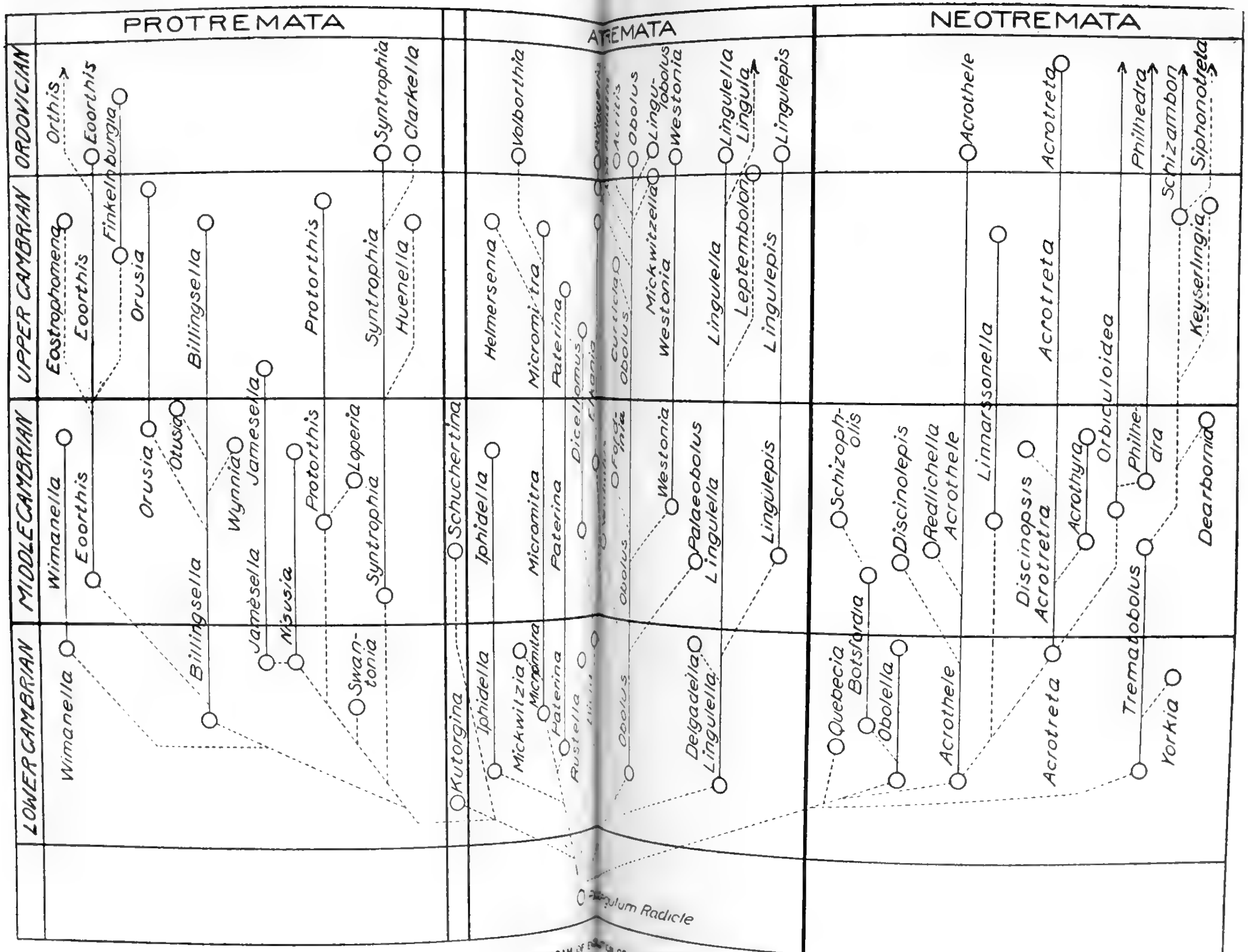


OF CAMBRIAN BRACHIOPODA



SCHEMATIC DIAGRAM OF EVOLUTION OF CAMBRIAN BRACHIOPODA

DEVELOPMENT IN CAMBRIAN TIME

We do not know of any brachiopoda in strata older than that containing the *Olenellus* or Lower Cambrian fauna. That such existed in pre-Cambrian time seems almost certain when the advanced stage of development of some of the earliest known forms is considered.

In the preceding diagram the known occurrence of the families of brachiopoda in strata of Cambrian age is graphically shown. The diagram is based on the data contained in tables prepared for the monograph giving a summary by families. The Obolidæ, with 7 genera, 9 subgenera, 183 species, and 17 varieties, has the greatest development, and the family continues into the base of the Ordovician with 2 genera, 7 subgenera, and 36 species. The Acrotretidæ has 6 genera, 1 subgenus, 93 species, and 19 varieties, with the greatest development in the Middle Cambrian and with a smaller representation in the Lower Ordovician. The Billingsellidæ, with 9 genera, 2 subgenera, 95 species, and 12 varieties, has a strong development in the upper Middle Cambrian and passes into the Ordovician, where it disappears. The three families mentioned include about 48 per cent of the genera, 80 per cent of the subgenera, 81 per cent of the species, and 81 per cent of the varieties included in the Cambrian brachiopoda. The development of genera of the remaining families containing 3 genera or more is as follows: Paterinidæ, 4; Obolellidæ, 4; Siphonotretidæ, 6; Syntrophiidæ, 3; or 17 genera of the 24 outside of the Obolidæ, Acrotretidæ, and Billingsellidæ, which contain 23 genera. The remaining 7 families include 7 genera.

Of the 46 genera from the Cambrian, 20 occur in the Lower Cambrian, 31 in the Middle Cambrian, and 23 in the Upper Cambrian.

SCHEME OF CLASSIFICATION

In order that we may have a graphic illustration to aid in description, the following table is inserted. The ordinal classification of Beecher [1891], with emendations, is taken as the basis for the orders, while the arrangement of superfamilies is practically that of Schuchert [1897], with such emendations and additions as greater information has rendered necessary. Dr. Charles Schuchert has been most helpful in discussion and criticism of this scheme of classification, and I am also indebted to Mr. E. O. Ulrich for a discussion of the classification of the Protremata. Due acknowledgment will be made in the monograph to many persons who have aided in various ways in making the monograph much more complete and useful than it otherwise would have been.

TABLE OF CLASSIFICATION.

- ATREMATA
  - Rustellacea
    - Rustellidæ
      - Rustella
    - Paterinidæ
      - Mickwitzia
      - Micromitra
        - (Paterina)
        - (Iphidella)
      - Volborthia
      - (?)Helmersenia
  - Obolacea
    - Curticiidæ
      - Curticia
    - Obolidæ
      - Obolinæ
        - Obolus
          - (Bröggeria)
          - (Palæobolus)
          - (Fordinia)
          - (Lingulobolus)
          - (Mickwitzella)
          - (Acritis)
          - (Schmidtia)
          - (Westonia)
        - Lingulella
          - (Leptembolon)
          - (Lingulepis)
        - Delgadella
      - Elkaniinæ
        - Elkania
      - Neobolinæ
        - Neobolus
      - Biciinæ
        - Bicia
        - Dicellomus
  - Kutorginacea
    - Kutorginidæ
      - Kutorgina
    - Schuchertinidæ
      - Schuchertina
- NEOTREMATA
  - Siphonotretacea
    - Obolellidæ
      - Obolella
        - (Glyptias)
      - Botsfordia
      - Schizopholis
      - (?)Quebecia
    - Siphonotretidæ
      - Yorkia
      - Dearbornia
      - Trematobolus
      - Schizambon
      - Siphonotreta
      - Keyserlingia
  - Acrotretacea
    - Acrotretidæ
      - Acrothelinæ
        - Acrothele
          - (Redlichella)
        - Discinolepis
      - Acrotretinæ
        - Linnarssonella
        - Acrotreta
        - Acrothyra
        - Discinopsis
  - Discinacea
    - Discinidæ
      - Orbiculoidea
  - Craniacea
    - Craniidæ
      - Philhedra
- PROTREMATA
  - Orthacea
    - Billingsellidæ
      - Nisusiinæ
        - Nisusia
          - (Jamesella)
        - Protorthis
          - (Loperia)
      - Billingsellinæ
        - Wimanella
        - Billingsella
        - Orusia
        - Otusia
        - Wynnia
      - Eoorthinæ
        - Eoorthis
        - Finkelnburgia
  - Strophomenacea
    - Strophomenidæ
      - Rafinesquinæ
        - Eostrophomena
  - Pentameracea
    - Syntrophiidæ
      - (?)Swantonia
      - Syntrophia
      - Huenella
      - Clarkella

Order ATREMATA Beecher, 1891 (emend)

Primitive inarticulate, corneous or calcareo-phosphatic Brachiopoda with the pedicle emerging more or less freely between the two valves. Growth takes place in general around the anterior and lateral margins. Specialized forms show tendency to develop rudimentary articulation. Delthyrium originally unmodified, in later genera modified by pseudodeltidia and pseudochilidia, or by thick-

ened, striated, and more or less furrowed or even cleft vertical cardinal margins, the ventral cleft in most specialized forms tending to enclose the pedicle and finally restrict it to the ventral valve; when completely so the genera are referred to the order Neotremata.

Superfamily RUSTELLACEA Walcott, new

Primitive, thick-shelled, corneous or calcareo-phosphatic Atremata developing more or less of pseudodeltidia and pseudochilidia.

Family RUSTELLIDÆ Walcott, new

Primitive Rustellacea with the delthyrium small, open, and not much modified by pseudodeltidia or pseudochilidia. Muscle scars and vascular sinuses not well defined in the shell.

Rustella

Family PATERINIDÆ Schuchert, 1893 (emend)

Progressive Rustellacea with the delthyrium more or less closed by pseudodeltidia or pseudochilidia.

Mickwitzia
Micromitra
    (*Paterina*)
    (*Iphidella*)
Volborthia
(?) *Helmersenia*

Superfamily OBOLACEA Schuchert, 1896 (emend)

Derived (in Rustellacea), progressive, thick-shelled, calcareo-phosphatic or corneous Atremata without pseudodeltidia and pseudochilidia. Rounded or linguloid in outline, more or less lens-shaped and fixed by a short pedicle throughout life to extraneous objects.

Family CURTICIIDÆ Walcott and Schuchert, new

Primitive Obolacea with a high, well-defined delthyrium. Interior characters much as in Obolidæ.

Curticia

Family OBOLIDÆ King, 1846 (emend)

Derived, progressive Obolacea with thickened, striated, vertical cardinal areas traversed by pedicle grooves. Muscles and vascular trunks strongly impressed in the valves.

Subfamily OBOLINÆ Dall, 1870 (emend)

Primitive Obolidæ with the pedicle grooves more or less shallow or deeply rounded, but never tending to form a sheath or to com-

pletely restrict the pedicle opening to the ventral valve. The radicle of the Trimerellidæ, by way of the Neobolinæ, appears to be in this subfamily in the thick-shelled Middle Cambrian forms of *Obolus* (s. s.)

Obolus
(*Bröggeria*)
(*Palæobolus*)
(*Fordinia*)
(*Lingulobolus*)
(*Mickwitzella*)
(*Acritis*)
(*Schmidtia*)
(*Westonia*)
Lingulella
(*Leptembolon*)
(*Lingulepis*)
Delgadella

Subfamily ELKANIINÆ Walcott and Schuchert, new

Divergent Obolidæ with posterior or marginal (not central) platforms, to which are attached the central and outside and middle lateral muscles.

Elkania

Subfamily NEOBOLINÆ Walcott and Schuchert, new

Progressive Obolidæ with posterior platforms, to which were probably attached the central and outside and middle lateral muscles. Subfamily apparently progressive from the Obolinæ to the Trimerellidæ, though the platform is posterior and not subcentral as in the Trimerelloids.

Neobolus

Subfamily BICIINÆ Walcott and Schuchert, new

Progressive Obolidæ with the pedicle restricted to the ventral valve and more or less enclosed by a pedicle tube, and with rudimentary articulation. The transgressing stock from the Atremata to the Neotremata (Obolellidæ).

Bicia
Dicellomus

Superfamily KUTORGINACEA Walcott and Schuchert, new

Progressive, thick-shelled, almost calcareous Atrematous-like shells, tending to be transverse and developing rudimentary articulation, more or less rudimentary cardinal areas, pseudodeltidia, and

muscle scars prophetic of the Protremata. Derived out of Rustellacea.

Family KUTORGINIDÆ Schuchert, 1893

Progressive transverse Kutorginacea with rudimentary cardinal areas, great delthyrial opening, rudimentary articulation, and immature pseudodeltidia. Muscle scars prophetic of the Strophomenacea.

Kutorgina

Family SCHUCHERTINIDÆ Walcott, new

Primitive round Kutorginacea with small cardinal areas. Externally like *Obolus,* with an open subtriangular delthyrium which apparently is without a pseudodeltidium. Muscle scars and vascular markings prophetic, through the Billingsellidæ, of the Strophomenacea.

Schuchertina

Order NEOTREMATA Beecher, 1891 (emend)

Derived and specialized inarticulate Brachiopoda (through the Obolidæ of the Atremata), as a rule more phosphatic than calcareous, more or less cone-shaped, with the pedicle emerging during life through a perforation or sheath in the ventral valve, or a triangular, more or less open cleft, or only so in the youngest shelled stage, after which the ventral valve becomes attached by a pedicle to foreign objects. Pedicle cleft in derived forms modified by a listrium. Pseudodeltidia and pseudochilidia as a rule not well developed.

Superfamily SIPHONOTRETACEA Walcott and Schuchert, new

Primitive, thick-shelled, calcareous or corneous, oboloid Neotremata, with the pedicle passing through a ventral sheath, the aperture of which may remain apical and circular in outline, or it may become elongate through resorption by passing anteriorly through the protegulum and umbo of the shell. A listrium is not developed. Dorsal protegulum marginal.

Family OBOLELLIDÆ Walcott and Schuchert, new

Primitive Siphonotretacea with the pedicle emerging through a small circular perforation in the apex of the ventral valve, posterior to the protegulum. Derived out of the Obolidæ.

Obolella

(*Glyptias*)

Botsfordia

Schizopholis

(?) *Quebecia*

Family SIPHONOTRETIDÆ Kutorga, 1848 (emend)

Progressive Siphonotretacea with the circular or elongate pedicle opening at the apex or passing by resorption anteriorly through the protegulum and the umbo of the shell.

Yorkia
Dearbornia
Trematobolus
Schizambon
Siphonotreta
Keyserlingia

Superfamily ACROTRETACEA Schuchert, 1896 (emend)

Progressive Neotremata with corneous or calcareo-corneous shells. The pedicle opening is a simple, circular, more or less conspicuous perforation through the apex of the ventral valve. Dorsal protegulum marginal.

Family ACROTRETIDÆ Schuchert, 1893

Same characters as superfamily.

Subfamily ACROTHELINÆ Walcott and Schuchert, new

Depressed, large Acrotretidæ.

Acrothele
    (*Redlichella*)
Discinolepsis

Subfamily ACROTRETINÆ Walcott and Schuchert, new

Small Acrotretidæ with more or less high ventral valves.

Linnarssonella
Acrotreta
Acrothyra
Discinopsis

Superfamily DISCINACEA Waagen, 1885

Derived Neotremata with phosphatic shells, a listrium modifying the pedicle slit, and without pseudodeltidia and false cardinal areas. Dorsal protegulum usually subcentral.

Family DISCINIDÆ Gray, 1840

Discinacea with an open pedicle notch in early life in the posterior margin of the ventral valve, which is closed posteriorly during

neanic growth, leaving a more or less long, narrow slit partially closed by the listrium.

Orbiculoidea

Superfamily CRANIACEA Waagen, 1885

Cemented calcareous specialized Neotremata without pedicle or anal openings at maturity.

Family CRANIIDÆ King, 1846

Craniacea with the pedicle functional probably only during nepionic growth.

Philhedra

Order PROTREMATA Beecher, 1891 (emend)

Progressive (though atrematous Kutorginacea), articulate calcareous Brachiopoda with well-developed cardinal areas. The pedicle opening is restricted to the ventral valve throughout life or during early growth and is often modified and more or less closed by a deltidium. Often there is a chilidum. Brachia unsupported by a calcareous skeleton other than crura.

Superfamily ORTHACEA Walcott and Schuchert, new

Derived, progressive Protemata. Cruralia and rudimentary spondylia (pseudospondylia) free or cemented (through sessility) directly to the valves. Sometimes without deltidia and chilidia. Cardinal process more or less well-developed except in the most primitive genera.

Family BILLINGSELLIDÆ Schuchert, 1893

Primitive Orthacea with an open or more or less closed delthyrium. Cardinal process well developed, rudimentary, or absent. Usually with a clearly defined pseudospondylium, to which the muscles of the ventral valve were attached. Shell structure dense, granular, lamellar, non-fibrous.

Subfamily NISUSIINÆ Walcott and Schuchert, new

Primitive Orthacea with more or less well-developed deltidia and with or without rudimentary chilidia. Spondylia and cruralia rudimentary or small and not supported by septa. Cardinal process rudimentary or absent.

Nisusia
(*Jamesella*)
Protorthis
(*Loperia*)

Subfamily BILLINGSELLINÆ Schuchert, 1893

Primitive Orthacea very much like Nisusiinæ but without true spondylia and cruralia. There is a more or less well-developed cardinal process except in Lower Cambrian forms.

Wimanella
Billingsella
Orusia
Otusia
Wynnia

Subfamily EOORTHINÆ Walcott, new

Derived Orthacea nearly always with large open delthyria; deltidia and chilidia occasionally retained throughout life, but more often only in the younger growth stages. Cardinal process well developed. Shell structure dense, granular, and with punctate lamellæ.

Eoorthis
Finkelnburgia

Superfamily STROPHOMENACEA Schuchert, 1896

Derived, progressive, terminal Protremata, out of Orthacea (Billingsellidæ). Deltidia and chilidia nearly always well developed. Cardinal process always well developed.

Family STROPHOMENIDÆ King, 1846

Subfamily RAFINESQUINÆ Schuchert, 1893

Strophomenoids having generally a convex ventral and a concave or nearly flat dorsal valve.

Eostrophomena

Superfamily PENTAMERACEA Schuchert, 1896 (emend)

Specialized Protremata with well-developed free or supported spondylia and cruralia. Deltidia and chilidia usually absent.

Family SYNTROPHIIDÆ Schuchert, 1896

Primitive Pentameracea with long, straight cardinal areas.

(?) *Swantonia*
Syntrophia
Huenella
Clarkella

STRUCTURE OF THE SHELL

The classification of the Protrematous genera is so profoundly influenced by the structure of the shell that it was decided to include the following notes:

The general structural characters of the shell of the Ordovician and later brachiopoda have been so fully described by authors that it does not appear to be necessary or desirable to repeat them. The student will find a full description given by Messrs. Hall and Clarke in their "Introduction to the Study of the Brachiopoda" [1892, pp. 150–225].

Some of the more important works that contain data on the structure of the shell are Hancock, "On the Organization of the Brachiopoda" [1859, pp. 791–869]; King, "On Some Characters of *Lingula anatina*" [1873, pp. 1–17]; Carpenter, "On the Intimate Structure of the Shells of Brachiopods" [1853, pp. 23–45]; Davidson, "On the Classification of the Brachiopoda" [1853, pp. 41–136]; and Mickwitz, "Ueber die Brachiopodengattung *Obolus*" [1896].

The greater proportion of the Cambrian brachiopoda is largely corneous or chitinous. These brachiopoda are restricted to the inarticulates, but the inarticulates of the Cambrian do not all possess corneous shells. Dr. Mickwitz has shown [1896, pp. 102–142] that the shells of *Obolus* and its subgenera are essentially the same as those of *Lingula* in composition and structure. In both the shells are composed of successive calcareous and corneous lamellæ that vary in thickness and structure. The calcareous lamellæ are prismatic and penetrated by minute tubules; the corneous lamellæ are compact and imperforate.

Messrs. Hall and Clarke, in speaking of the shells of the articulate brachiopoda, say: "Among the articulate genera, under favorable preservation, there may be distinguished three distinct calcareous shell layers: an inner prismatic or fibrous layer, which constitutes the greater portion of the shell; above this is a thin lamellar layer, and the outer surface of the shell is covered by a tenuous epidermal film or periostracum. When the shell is punctate the tubules open on the inner surface in narrow apertures, whence they widen upwards, abruptly expanding in the lamellar layer, at whose upper margin they terminate. They do not pierce the periostracum." [1892, p. 175.]

Among the calcareous, inarticulate brachiopoda the shell of the Cambrian genus *Obolella* shows a dense, compact, slightly lamellated structure made up of a granular ground-mass pierced by extremely small tubules or pores. The substance of the shell of *Rustella* and

Yorkia is unknown, but from the character of the casts and the fact that the shells of *Micromitra* in the same matrix are preserved, it is probable that it was calcareous. The shells of *Quebecia, Trematobolus,* and *Dearbornia* are also calcareous.

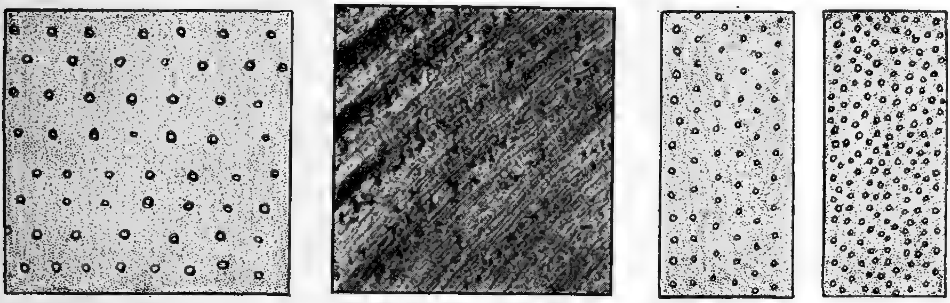
In *Kutorgina* and *Schuchertina,* forms that may be referred to either the Atremata or the Protremata, the shells appear to be calcareous, compact, and without fibrous structure. Messrs. Hall and Clarke, when speaking [1892, p. 174] of the composition of the shell of fossil linguloids, said: "In the group of fossil linguloids, beginning with *Lingula,* passing through *Lingulops* and *Lingulasma* to *Trimerella* and its allies, there is a regular increase in the relative amount of calcareous matter in the shell, so that the *Trimerellas,* which are large and ponderous shells, seem to have wholly lost their corneous matter."

The predominance of corneous or calcareous shell matter does not appear to be of more than generic importance in the classification of the brachiopoda. It is true that the known articulate genera are all calcareous, but it is equally true that among the inarticulate group calcareous shells occur. Alteration, replacement, and removement of original shell substance have changed the shell of so many species that other characters must be depended upon for classification.

Microscopic Structure of the Cambrian Brachiopoda.—In previous work on the Cambrian Brachiopoda, except in the cases above cited, practically no attention has been paid to their microscopic shell structure. The importance of this feature in the classification of later species suggested the possible value of a microscopic study of the earlier forms, and at my request Mr. R. S. Bassler, of the United States National Museum, prepared thin-sections and also assisted in the preparation of the accompanying illustrations and in the preliminary study of the sections.

The preparation of thin-sections of these early brachiopoda is accompanied with difficulties which, together with the lack of sufficiently extensive collections, have undoubtedly prevented previous study along the same line. Specimens suitable for sectioning, especially of the calcareous forms, are not at all common, and when they do occur they are almost invariably buried in the rock, and are so thin that the parting of the enclosing matrix does not leave sufficient shell substance for the preparation of sections. In the present work the specific identity of a shell was first determined by uncovering about one-half the valve, and the other half, still embedded in the matrix, was then used in making the section. The structural features are often restricted to individual lamellæ, and the right zone

for microscopic examination was determined simply by close observation as grinding proceeded. Both vertical and tangential sections were prepared, the former cutting the shell at right angles and the latter cutting the shell in planes more or less parallel to the layers or lamellæ of which it is composed. The most interesting results were obtained from the tangential sections, as the thin shells showed little decided structure in vertical sections.



2 3 4 5

FIG. 2. *Billingsella plicatella* Walcott [1905, p. 240]. Upper Cambrian, Gallatin Valley, Montana.

Diagrammatic sketch of a small portion of a tangential section, × 200. The granular ground-mass, with small pores and tubules 4 or 5 times their own diameter distant from each other, is also typical of other members of the Billingsellidæ.

FIG. 3. *Dalmanella subequata* (Conrad) [1843, p. 333]. Ordovician (Stones River), St. Paul, Minnesota.

Photograph of a tangential section, × 35, showing the fibrous structure and comparatively large pores.

FIG. 4. *Kutorgina cingulata* (Billings) [1861, p. 8]. Lower Cambrian, Swanton, Vermont.

A small portion of the tangential section figured on Plate 12, fig. 4, × 200. The minute structure of this and the following species is essentially the same as that shown in fig. 1, the only difference being the closer arrangement of the pores.

FIG. 5. *Obolus apollinis* Eichwald [1829, p. 274]. Upper Cambrian Obolus sandstone, Esthonia, Russia.

Small portion of tangential section × 200. The minutely porous granular structure is beautifully shown in this species, in which the pores are arranged more closely than in any other observed.

The general resemblance of the Cambrian eoorthoids to certain Ordovician Protremata is so striking and the lines of descent so suggestive that particular attention was devoted to this group, and the examination brought out the fact that this apparent relationship disappears when the shell structure of the two groups is compared.

Sections of the shells of members of the Billingsellidæ, of which

figure 2 is typical, all show a lamellar structure with indications of more or less numerous and scattered, very minute pores or tubules passing without interruption through one lamella. In some sections the spots indicating the tubules are arranged in rows radiating from the beak of the shell to the margins, but no other regular arrangement can be seen. The great mass of the shell is made up of a compact, finely granular base with dark spots and occasional minute crystals of calcite—a ground-mass which, under the microscope, appears very much like that of a fine argillaceous shale.

The Ordovician Protremata have a clearer, more crystalline aspect or color than the Cambrian Billingsellidæ—a difference which probably indicates either a purer lime composition for the former or more probably a higher percentage of calcium phosphate for the latter. In chemical aspect the shells of the Billingsellidæ appear to resemble those of the Atremata and Neotremata more closely than do the Orthidæ. Analyses of the respective shells would be necessary to prove these relations, but to note them is interesting in view of the possible derivation of the Billingsellidæ from the Atremata.

In the Cambrian articulate genera, with the possible exception of *Syntrophia* and *Huenella,* there is an entire absence of the minute, fibrous structure so characteristic of most, if not all, orthoids. But these two representatives of the Pentameracea greatly resemble each other. Thus sections of the shell of *Huenella abnormis* (Walcott) of the Upper Cambrian (see pl. 12, fig. 9) and *Syntrophia lateralis* (Whitfield) of the Lower Ordovician (see pl. 12, fig. 7) show the same radial arrangement of the pores seen in the Billingsellidæ, but the shell structure is fibrous and the rows are coincident in direction with the fibers. Upon closer study this apparent fibrous structure can be resolved into more or less parallel bands or walls of shell substance separating rows of closely arranged, rectangular, pore-like spaces. These spaces may be seen distinctly in thick sections, but when the section is made sufficiently thin to give a clear image under very high power, the pore structure disappears.

Sections of the linguloid genera were also prepared and studied, but the thinness of the shells and their phosphatic character prevented very satisfactory results. The irregular large tubules mentioned by Dr. Mickwitz [1896] are beautifully shown in the sections of *Obolus apollinis* before me. Some of the tubules penetrate several lamellæ of the shell and suggest the tubules of some of the orthoids. (See figures 11 and 12, pl. 12.) The same general structure, with the exception of the larger tubules, appears to be characteristic of all of

the corneous shells of the Atremata and Neotremata, and, as far as known to me, all of the Cambrian corneous shells are of this type.

The figures on the accompanying plate, with the exception of figures 11 and 12, are from photographs which have not been retouched. Unfortunately higher magnifications could not be used without a loss of clearness; but, even at the present magnification, these views show a decided difference in structure.

In conclusion, it appears that the Cambrian Billingsellidæ are further removed from the Ordovician and later Protremata than hitherto suspected, the microscopic shell structure in the former being of granular material pierced by small pores and in the latter of fibrous material. On the other hand, the microscopic structure of the Cambrian and later Pentameracea is so similar that an unbroken line of descent is indicated.

TERMINOLOGY RELATING TO THE SHELL

The definitions given in the following pages are largely those of Schuchert [1897, pp. 73–75], with the exception of the muscle scars of the inarticulate brachiopods. For the Atremata and Neotremata the terminology proposed by Professor William King [1873, pp. 5, 6] is adopted, and for the Protremata that used by Messrs. Hall and Clarke [1892, pp. 183–188] and given under the terminology of Schuchert [1897, pp. 73–77]. I agree with Messrs. Hall and Clarke that Professor King's terminology has claims for its adoption, owing to its simplicity. Dr. F. Blochmann has proposed [1900, p. 108] a set of terms for the muscles of the inarticulate brachiopods that has much to commend it. The terminology of Mr. Albany Hancock [1859, p. 800] has been extensively used by authors. The numbers below correspond to the numbers given the terminology of King, Schuchert, and Blochmann.

Hancock, 1859

Inarticulates	*Articulates*
1. Anterior occlusors.	1. Anterior occlusors.
2. Posterior occlusors.	2. Posterior occlusors.
3. Divaricator.	3. Accessory divaricators.
4. Central adjustors.	4. } Ventral adjustors.
5. External adjustors.	5. }
6. Posterior adjustors.	6. Dorsal adjustors.
7. Peduncular.	7. Peduncular.

King, 1873

1. Anterior laterals.
2. Centrals.
3. Umbonal.
4. Transmedians.
5. Outside laterals.
6. Middle laterals.

Schuchert, 1897

1. Retractors.
2. Adductors.
3. Pedicle.
4. Rotators.
5. Protractors (externals).
6. Protractors (middles).
7. Diductors.

Blochmann, 1900

1. Lateralis.
2. Occlusor anterior.
3. Occlusor posterior.
4. Obliquus internus.
5. Obliquus externus.
6. Obliquus medius.

DEFINITIONS

Adductor Muscles.—(See Central muscles.) The term adductor is used for the central muscles of the Protremata.

Anterior Lateral (Retractor) Muscles.—In the Atremata these extend from the outer lateral margins of the visceral area in the ventral valve to its anterior extremity in the dorsal valve and serve to readjust the dorsal shell.

Anterior Region.—That portion of the shell in front of the transverse axis and opposite the pedicle opening.

Apex.—The place of initial shell growth. It may be the most posterior portion of the valve or it may be situated near the transverse axis.

Apical Callosity.—The thickened boss at the inner side of the apex of the ventral valve of *Acrotreta* and other Neotrematous genera through which the pedicle tube or foramen passes.

Area.—See Cardinal area.

Articulate Brachiopoda.—In the orders Protremata and Telotremata the valves articulate by means of teeth and sockets. In some Atremata rudimentary articulation is also developed.

Atremata.—Primitive inarticulate, calcareo-phosphatic or corneous brachiopods with the pedicle emerging more or less freely between the two valves. (For a more detailed description see page 142.)

Brachia.—The fleshy, coiled or spiral, ciliated appendages of brachiopods serving in water circulation and respiration.

Brachiocœle.—All of the anterior half of the valves outside of the anterior portion of the parietal band. (After King.)

Cardinal Area.—A more or less well-developed triangular area on each side of the delthyrium, distinctly set off from the general surface of the shell. It is best developed on the ventral valve of articulate brachiopods, but is also present on the dorsal valve, and generally in a rudimentary condition in many inarticulate species. When the area is rudimentary it is often called a false or pseudo-area. The area of some of the inarticulate genera is frequently divided by a line between the delthyrium and the outer margin. In such areas the line is called the flexure line, owing to the slight interruption in the striæ of growth, and the spaces separated by the flexure line are called the inner and outer lateral spaces of the area. (See Deltidium and Foramen.)

Cardinal Extremities.—The terminations of the hinge line.

Cardinal Muscle Scar.—A large scar within which the posterior and anterior lateral and transmedian muscle scars were attached.

Cardinal Process.—A variously modified apophysis, situated posteriorly at the center of the hinge of the dorsal valve in articulate brachiopoda. To it are attached the diductor muscles, which by their contraction serve to open the valves anteriorly.

Cardinal Slopes.—The inclined surfaces extending from the umbonal slopes to the hinge margins.

Central (Adductor) Muscles.—In the Protremata and Telotremata these muscles have their ventral insertion one on either side of the central axis, between the diductors. In passing to the dorsal valve they divide into four and produce in that shell the two pairs of principal scars known as the anterior and posterior centrals. By contraction these muscles close the shell. In the Neotremata they are the essential muscles, the anterior centrals closing the valves, while the posterior pair serves to open the valves. In the Atremata there is a simple pair of centrals placed near the anterior extremity of the visceral area.

Chilidium.—A dorsal plate, in appearance similar to the deltidium, covering the exterior portion of the cardinal process in many Protremata. Its development does not begin until early neanic or later growth and it is probably secreted by the dorsal mantle lobe. In the Atremata and Neotremata there is a similar plate continuous with the dorsal cardinal region of the shell, and it is named the pseudochilidium.

Crura.—Processes on the dorsal hinge plate of the Telotremata and some Protremata, to which are attached the fleshy brachia and brachidia. These usually form the inner walls of the dental sockets and may be supported by septal plates.

CRURALIUM.—The dorsal equivalent of the ventral spondylium.

DELTHYRIUM.—The triangular aperture transecting medially the ventral cardinal area, or the posterior surface from the apex to the posterior margin of the ventral valve, through some portion of which the pedicle passes. It has also been termed the *fissure* or *foramen*. The delthyrium may or may not be closed either by a calcareous deltidium or a phosphatic pseudodeltidium.

DELTIDIUM.—A plate more or less continuous with the cardinal margin on the ventral valve covering the delthyrium in Atremata, Neotremata, and Protremata. When present in inarticulate brachiopods it is called the pseudodeltidium, and in the Protremata, where it is always more calcareous, thicker, and more sharply defined, the deltidium and pseudochilidium.

DENTAL PLATES.—Vertical plates supporting the teeth of the ventral valve in articulate brachiopods.

DENTAL SOCKETS.—Excavations in the dorsal cardinal margin of articulate brachiopods in which the teeth of the ventral valve articulate. The inner wall of the socket is elevated and forms the base of the crural plate.

DIDUCTOR MUSCLES.—In the Protremata and Telotremata the principal pair of diductor muscles has the larger end attached to the ventral valve near the anterior edge of the visceral area, while the other end has its insertion on the anterior portion of the cardinal process. By contraction these muscles open the valves.

DORSAL VALVE.—Usually the smaller and imperforate valve and the one to which the brachia are always attached. *Brachial, hæmal, socket,* and *entering* valves are other terms more rarely employed.

EPHEBIC.—Designating the mature shell.

FALSE AREA.—See Cardinal area.

FLEXURE LINE.—See Cardinal area.

FORAMEN.—A small circular passage through the deltidium, either below or at the apex of the ventral valve. Sometimes the foramen encroaches by pedicle abrasion upon the umbo of the ventral valve.

FORAMINAL TUBE.—The pedicle opening through the ventral valve of Neotrematous genera.

GENITAL MARKINGS.—Radial markings or pits within the posterior portion of the visceral space, indicating the position and extent of the genitals.

GERONTIC.—Designating old age. It is indicated in the ontogeny of many species of brachiopods by extreme thickness of the valves, obesity, or by numerous, crowded growth lines near the anterior margin—a condition which sometimes produces truncation and absence of striæ at the margin.

HEART-SHAPED CAVITY.—Central depressed portion of visceral area (Mickwitz).

HINGE LINE.—The line along which articulation takes place; also sometimes developed among inarticulate brachiopoda.

INARTICULATE BRACHIOPODA.—In the orders Atremata and Neotremata the valves do not, as a rule, articulate by means of teeth and sockets, as is the case in the articulate orders Protremata and Telotremata.

LATERAL AREAS.—That portion of the shell on each side of the longitudinal axis.

LISTRIUM.—In some Neotremata a plate closing the progressive track of the pedicle opening or pedicle cleft, posterior to the apex of the ventral valve.

LONGITUDINAL AXIS.—A median line through the shell from the beak to the anterior margin.

MEDIAN SEPTUM.—An internal vertical plate commonly developed along the longitudinal axis and between the muscles of the ventral valve. Sometimes there is also a dorsal median septum. Lateral septa are rarely developed.

MIDDLE LATERAL MUSCLE SCAR.—See Outside lateral.

NEANIC.—Designating youthfulness, or the stage in which specific characters begin to develop.

NEOTREMATA.—Circular or oval, more or less cone-shaped, inarticulate calcareo-phosphatic brachiopods with the pedicle opening restricted throughout life to the ventral valve. (For a more detailed description see page 145.)

NEPIONIC.—Designating the smooth shell stage succeeding the protegulum.

OUTSIDE AND MIDDLE LATERAL (PROTRACTOR) MUSCLES.—In the Obolidæ one pair has the ventral ends fastened at the anterior extremity of the visceral area, extending backward and inserted near the lateral margin of the dorsal valve, outside the transmedians. A second pair originates just behind the centrals of the ventral valve and is inserted posterior to the first pair. These muscles draw the dorsal valve forward.

PARIETAL BAND.—The point of attachment of the muscular wall surrounding the visceral area.

PEDICLE.—The flexible muscular organ of the ventral valve by means of which brachiopods may be attached to extraneous objects.

PEDICLE FURROW.—The external furrow adjoining the foramen or pedicle opening in certain Neotrematous genera.

PEDICLE GROOVE.—The median groove on the cardinal areas of the valves formed by the pedicle extending through the posterior margin of the valves when they were closed.

PEDICLE MUSCLES.—In the Protremata and Telotremata one pair originates on the ventral valve at points just outside and behind the diductors, and another on the dorsal valve behind the posterior centrals, while the opposite ends of both are attached to the pedicle. Besides these, there is an unpaired muscle lying at the base of the pedicle, attaching it closely to the ventral valve.

PEDICLE OPENING.—See Delthyrium.

PEDICLE TUBE.—See Foraminal tube.

PLATFORM.—An internal median thickening of the shell elevating the muscles. Seen in certain families of the Atremata and more rarely in the Neotremata. (See Spondylium.)

PLEUROCŒLES.—Areas between the parietal band and the outer postero-lateral margins. (After King.)

POSTERIOR REGION.—That portion of the shell back of the transverse axis and toward the beak, or apex.

PROTEGULUM.—The initial shell of brachiopoda. It is smooth and of microscopic size, in outline being semicircular or arcuate and without cardinal areas. Rarely seen in adult shells.

PROTRACTOR MUSCLES.—See Outside and middle lateral muscles.

PROTREMATA.—Articulate, calcareous brachiopods, with the pedicle opening restricted to the ventral valve throughout life or during early growth. Pedicle aperture modified by the deltidium. Brachia unsupported by a calcareous skeleton, but nearly always by a more or less long crura. (For a more detailed description, see page 147.)

PSEUDO-AREA.—See Cardinal area.

PSEUDOCHILIDIUM.—See Chilidium.

PSEUDOCRURALIUM.—Dorsal equivalent of pseudospondylium.

PSEUDODELTIDIUM.—The convex medial portion continuous with the ventral cardinal areas in Atremata and Neotremata. (See Deltidium.)

PSEUDO-PEDICLE GROOVE.—See Pedicle groove.

PSEUDOSPONDYLIUM.—See Spondylium.

RETRACTOR MUSCLES.—See Anterior lateral muscles.

SEPTAL PLATES.—Plates supporting the crural processes; also known as *crural plates*.

SESSILE SPONDYLIUM = Pseudospondylium.

SPLANCHNOCŒLE.—The area within the parietal band. (After King.)

Spondylium.—A plate in some articulate brachiopoda, mainly the Pentameracea, formed by the union of converging dental plates, to the upper surface of which are attached the adductor, diductor, and pedicle muscles. The spondylium may rest upon the ventral valve or may be supported by a median septum. The spondylium appears to be first indicated in the articulates by a thickening of the shell of the ventral valve beneath the umbonal region so as to form an area upon which all the muscles of the valve have their points of attachment. In *Billingsella* this is beautifully illustrated by *B. exporecta* and *B. plicatella.* In its development the spondylium is foreshadowed in the Atremata by the so-called platform of *Fordinia* and the still more primitive form in *Obolus.* For the purpose of reference, the rudimentary spondylia attached directly to the inner surface of the valve, as in *Billingsella,* may be called pseudospondylia (sessile spondylia, Ulrich), and those free or supported by a septum or septa, spondylia. In the Cambrian Atremata the homologous equivalent has been known as the platform. In *Obolus,* etc., there is sometimes developed in the dorsal valve a plate similar in appearance to the spondylium, but different in origin and known as the cruralium.

Teeth.—Two processes of the ventral valve of articulate brachiopoda, serving for articulation.

Transmedian (Rotator) Muscles.—In Obolacea these are situated posteriorly just in advance of the umbonal muscle, two on one side and one on the other. By their contraction the dorsal valve turns alternately first in one direction and then in the other.

Transverse Axis.—A line through the shell from right to left, midway between the beak and anterior region. (See Longitudinal axis.)

Trapezoidal Area.—The area on each side of the heart-shaped cavity in *Obolus* in which the outside and middle lateral scars and central muscle scars are attached.

Umbo.—The elevated or prominent portion of the valve anterior to the apex.

Umbonal Cavity.—The hollow space in the interior of the shell beneath the umbo.

Umbonal Muscle.—A single muscle situated in the umbonal region of most Atremata. By its contraction the valves are opened anteriorly. In *Obolus* this muscle divides toward the ventral valve.

Umbonal Slopes.—The inclined surfaces about the umbo and opposite the cardinal slopes.

Ventral Valve.—Usually the larger valve situated on the ventral side of the animal. Among articulate brachiopoda the valve is usu-

ally easily distinguished by the presence of a delthyrium or pedicle opening through which the pedicle is protruded. In many Atrematous genera the ventral valve is not readily distinguished. When the shell is cemented to foreign bodies it is always by the ventral valve. It is usually the larger and deeper of the two valves. *Pedicle, larger, dental, neural,* and *receiving* valves are synonymous terms.

VASCULAR (PALLIAL) SINUSES.—Two convergent or divergent primary sinuses of the circulatory system, traversing the mantle and originating in the posterior medial region. They usually have numerous secondary (lateral and peripheral) branches and both often leave impressions in the shell.

VISCERAL AREA.—The posterior region of the interior of the valves between the pallial sinuses; in general, the immediate area of the median muscle tracks.

VISCERAL CAVITY = Visceral area.

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DESCRIPTION OF PLATE 12

Billingsella coloradoensis (Shumard) [1860, p. 627]:

FIG. 1. Photograph of horizontal thin-section enlarged fifty diameters. This shows the characteristic granular ground-mass of the Cambrian Billingsellidæ. Upper Cambrian, Morgan Creek, Burnet County, Texas.

Nisusia festinata (Billings) [1861, p. 10]:

FIG. 2. Photograph of horizontal thin-section enlarged fifty diameters. This section shows a granular ground-mass in which there are faint indications of small pores or tubulæ which may be seen with a high power. Lower Cambrian, 2 miles east of Swanton, Vermont.

Eoorthis remnicha (N. H. Winchell) [1886, p. 317]:

FIG. 3. Photograph of horizontal thin-section enlarged fifty diameters. This section shows the same type of ground-mass as that illustrated by fig. 2. Upper Cambrian, Cold Creek Canyon, Burnet County, Texas.

Kutorgina cingulata (Billings) [1861, p. 8]:

FIG. 4. Photograph of horizontal thin-section showing granular shell substance. There are few slight indications of pores. Lower Cambrian, Swanton, Vermont.

Dalmanella multisecta (Meek) [1873, p. 112]:

FIG. 5. Horizontal thin-section enlarged fifty diameters. This shows the fibrous structure of the shell penetrated by numerous fine tubules. Ordovician Eden formation, Cincinnati, Ohio.

Dalmanella parva (de Verneuil) [1845, p. 188]:

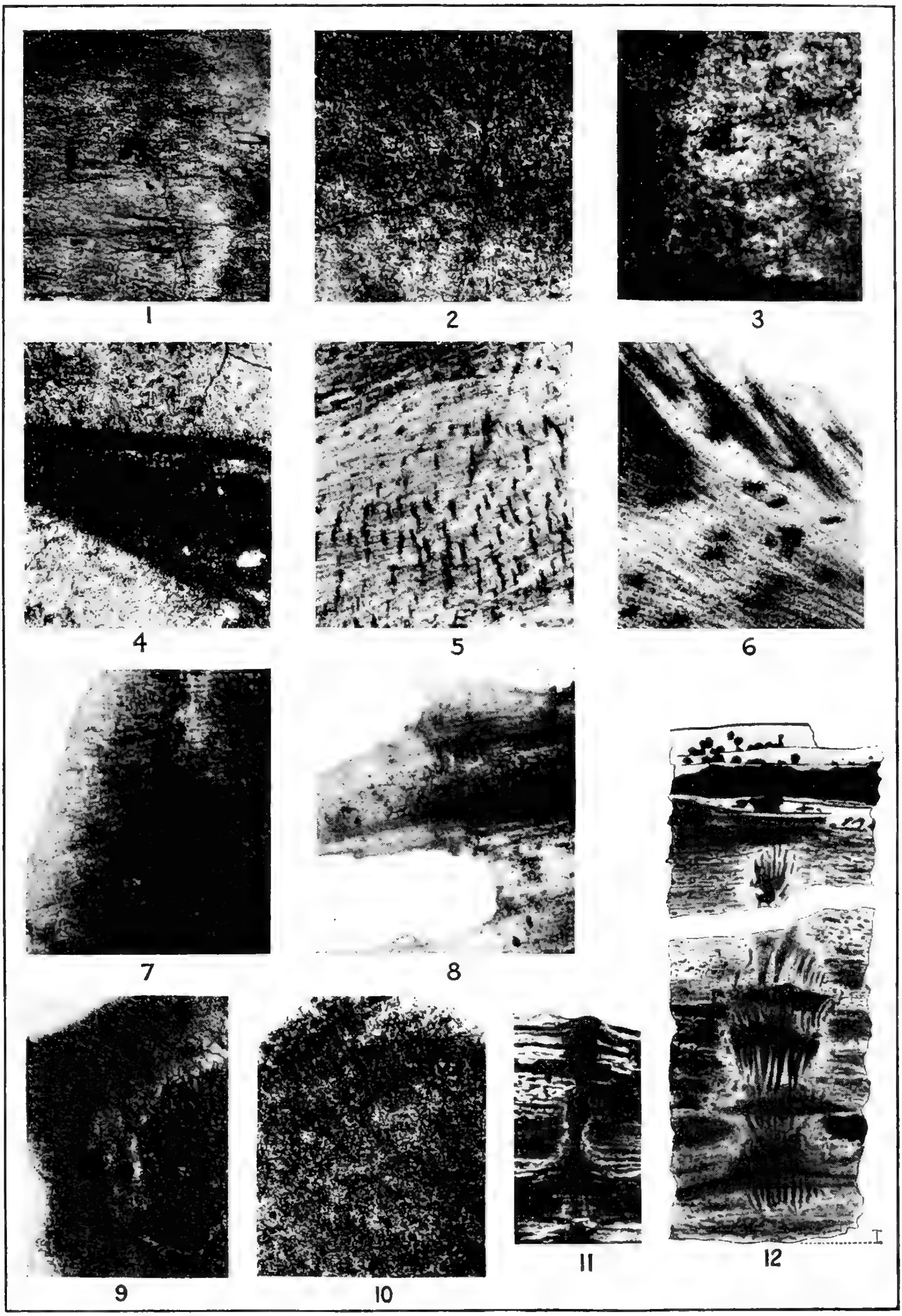
FIG. 6. Horizontal thin-section showing fibrous structure; also section of the tubules that penetrate through the shell. Middle Ordovician of Russia.

Syntrophia lateralis (Whitfield) [1886, p. 303]:

FIG. 7. Horizontal thin-section enlarged fifty diameters, showing the arrangement of the pores in lines that radiate from the apex toward the margin. Lower Ordovician Cassin limestone, Fort Cassin, Vermont.

Plectorthis plicatella (Hall) [1847, p. 122]:

FIG. 8. Horizontal thin-section enlarged fifty diameters. This section shows the fibrous structure so characteristic of the Ordovician orthoids. Ordovician Lorraine shaly limestones, Cincinnati, Ohio.



MICROPHOTOGRAPHS OF ROCK SECTIONS

Huenella abnormis (Walcott) [1905, p. 289]:

FIG. 9. Horizontal thin-section enlarged fifty diameters. The pores in this genus are smaller than in *Syntrophia,* but their arrangement is essentially the same and shows the line effect characteristic of the Pentameracea. Upper Cambrian, Gallatin Valley, Montana.

Obolella crassa (Hall) [1847, p. 290]:

FIG. 10. Horizontal thin-section enlarged fifty diameters. This shows the fine granular ground-mass, with an indication in the upper left side of the section that a surface ornamentation has been cut across. Lower Cambrian, Bic, Canada.

Obolus apollinis Eichwald [1829, p. 274]:

FIGS. 11 and 12. Transverse, vertical thin-section enlarged so to to show the lamellæ and the presence of a large tubule that appears to have more or less imperfectly penetrated through the shell. Upper Cambrian Obolus sandstone, Russia.

SMITHSONIAN MISCELLANEOUS COLLECTIONS

PART OF VOLUME LIII

CAMBRIAN GEOLOGY AND PALEONTOLOGY

No. 5.—CAMBRIAN SECTIONS OF THE CORDILLERAN AREA

WITH TEN PLATES

BY

CHARLES D. WALCOTT

No. 1812

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
DECEMBER 10, 1908

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Contents

Illustrations

INTRODUCTION

My first study of a great section of Paleozoic rocks of the western side of North America was that of the Grand Canyon of the Colorado River, Arizona. In this section the Cambrian strata extend down to the horizon of the central portion of the Middle Cambrian (Acadian) where the Cambrian rests unconformably on the pre-Cambrian formations.[1]

[1] See American Jour. Sci., 3d ser., xxvi, 1883, pp. 437–442.

The second section studied was that of the Eureka District of central Nevada in 1880–1881, the results of which were incorporated in Monographs VIII and XX of the U. S. Geological Survey. This section includes the upper portion of the Lower Cambrian (Georgian), the Middle Cambrian (Acadian), and the Upper Cambrian (Saratogan). The studies of the Cambrian strata were afterward continued in the Cordilleran area from time to time as opportunity offered. These included the Highland Range section of Nevada and the Big Cottonwood section of the Wasatch Mountains (see Bulletin U. S. Geol. Survey, No. 30, 1886, pp. 33 and 38). The great House Range section of central western Utah was studied and measured in 1905, the Blacksmith Fork section of the Wasatch Mountains in 1906, and the Mount Bosworth section of British Columbia in 1907. The last three sections are included in this paper.

The strata of the Lower Cambrian (Georgian) are apparently well developed in the Big Cottonwood section of Utah, and the upper portion in the House Range, Eureka, and Highland Range sections, but it was not until the sections of the Lower Cambrian (Georgian) formations of western Nevada and southeastern California were examined that the fauna was found well developed. These sections are incorporated in this paper.

Illustrations.—In order that geologists and paleontologists who have not had an opportunity to see the sections may get an idea of the completeness of the exposures of the strata in the Cordilleran area, photographs are introduced in connection with the House Range and Mount Bosworth sections.

The map of the House Range gives the localities and names used in the section.

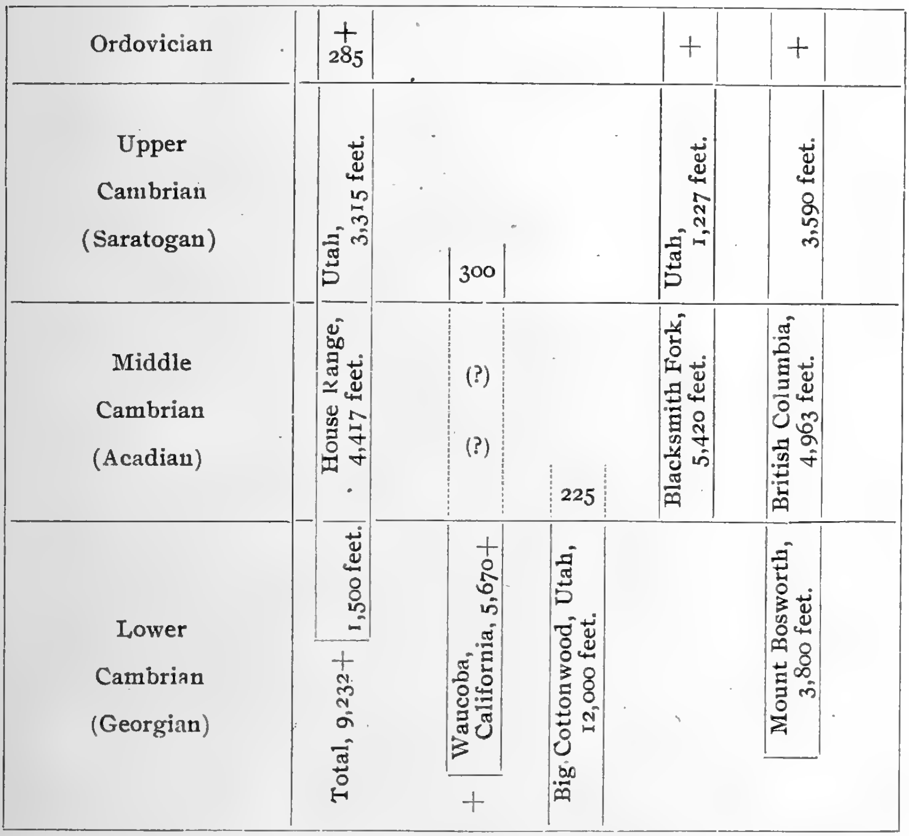
CORRELATION OF SECTIONS

The object of this preliminary correlation is to show in a broad way the interrelations of the strata and faunas in the North American Cordilleran area west of the great continental land area of Lower and much of Middle Cambrian time. The margin of this area was as far westward as the present position of the main range of the Wasatch Mountains in the vicinity of Salt Lake, Utah; from this point the shoreline trended gradually south-southwest to southwestern Utah and into southeastern Nevada. To the north of Salt Lake the trend of the early Cambrian shoreline was north-northeast to western Wyoming, and thence north into Montana (see Dearborn River section). It passed westward of the Belt Mountain

uplift, and thence north into Alberta, east of the Rocky Mountain front, where all traces of it are lost beneath the covering of Tertiary and Cretaceous rocks. In the vicinity of the international boundary (49th parallel) an uplift of pre-Cambrian (Beltian) strata appears to have largely prevented Cambrian sedimentation in northwestern Montana and northern Idaho. The faunas of the sections to the north in British Columbia and to the south in Utah clearly prove that the seas in which they lived were connected, but how or where we do not know.

In the following diagram the general relations of the sections are shown:

Table Showing Stratigraphic Position in the Cambrian System of Five of the Sections Described



The House Range section, supplemented by the Lower Cambrian sections of western Nevada and southeastern California, 230 miles (370.07 km.) west-southwest, gives a total of over 13,000 feet (3962 m.) of strata with Cambrian faunas throughout. If the Big Cottonwood section, 140 miles (225.26 km.) to the northeast of the

House Range, is found to have Cambrian fossils to its base, there will be over 19,000 feet of Cambrian strata in Utah. I think it quite probable that the quartzitic sandstones and siliceous shales of the Big Cottonwood section were being deposited as near-shore sediments while the calcareous, argillaceous, and arenaceous muds were accumulating at the same time 350 miles (563.15 km.) to the southwest.

The Upper and Middle Cambrian formations of the House Range section are much like those of the Blacksmith Fork and Mount Bosworth sections. From the top down the correlation of the various sections is as follows:

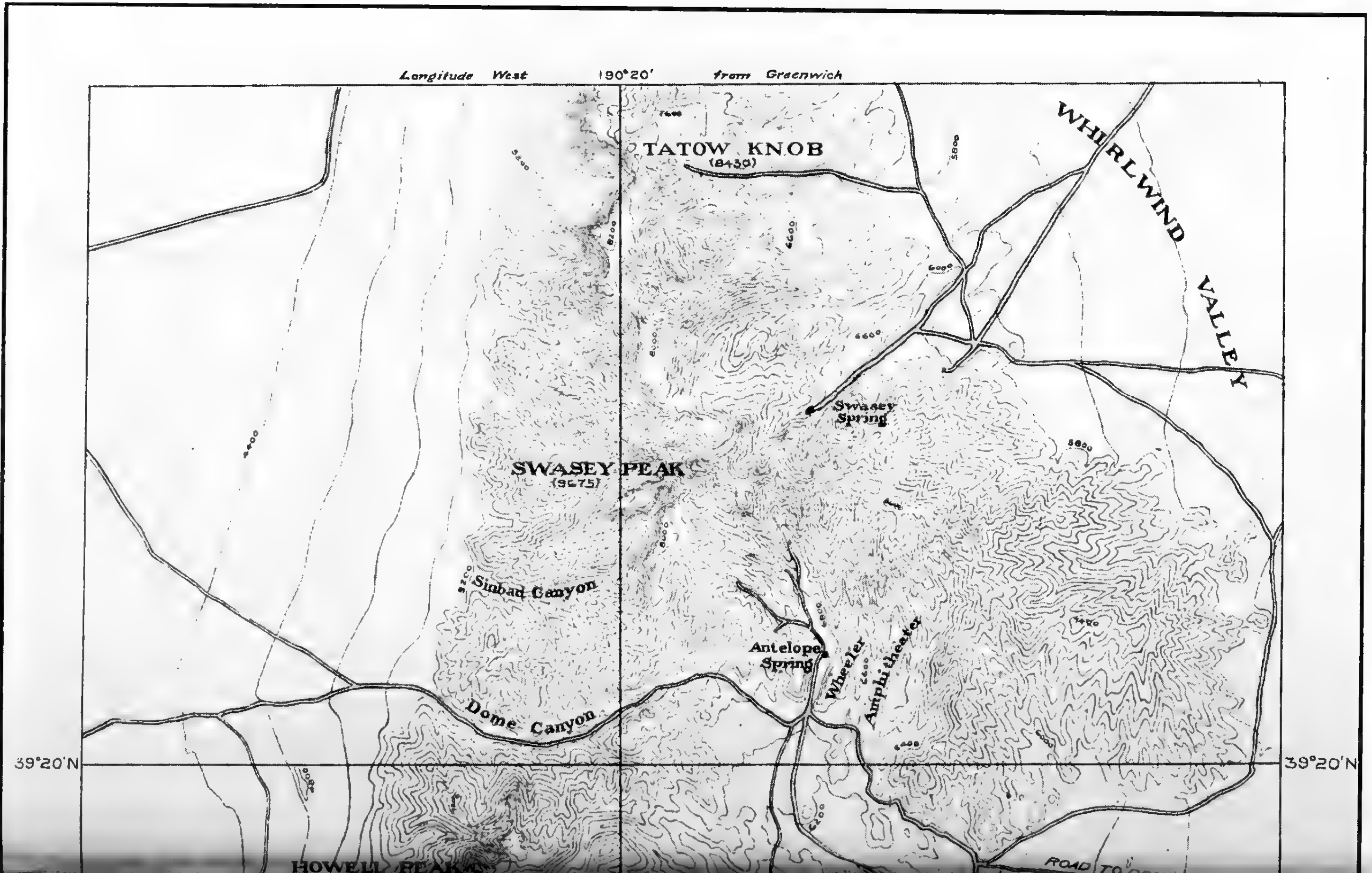
Correlation Table of Stratigraphic Sections

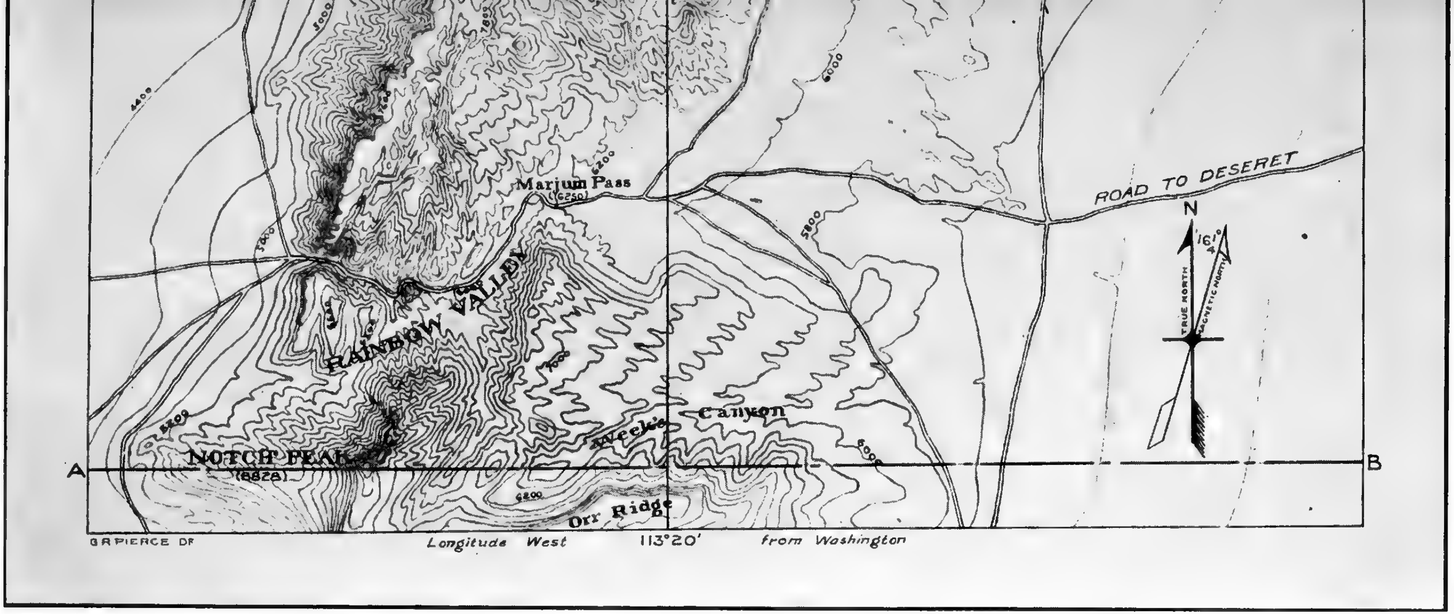
	House Range	Silver Peak	Big Cottonwood	Blacksmith Fork	Dearborn River	Mount Bosworth
Upper Cambrian (Saratogan)	Notch Peak, 1,490	Emigrant, 300	No Upper Cambrian	St. Charles, 1,227	(?)	Sherbrooke, 1,375
						Paget, 360
	Orr, 1,825					Bosworth, 1,855
Middle Cambrian (Acadian)	Weeks, 1,390	(?)		Nounan, 1,041	Limestone, 1,320	Eldon, 2,728
	Marjum, 1,102					
	Wheeler, 570			Bloomington, 1,320		
	Swasey, 340			Blacksmith, 570	Shale, 150	Stephen, 640
	Dome, 355	(?)	(?)	Ute, 729	Limestone, 130	
	Howell, 435					Cathedral, 1,595
	Spence, 20		Limestone, 75	Spence, 30	Shale, 210	
	Langston(?), 205		Shale, 150	Langston, 498	Limestone, 55	
Lower Cambrian (Georgian)	Pioche, 125	Silver Peak, 5,670 +	Shale, 100	Brigham, 1,232 +	Shale, 190	Mt. Whyte, 390
	Prospect Mountain, 1,375 +		Prospect Mountain, 11,750 +		Sandstone, 150	St. Piran, 2,705
					The sandstone rests unconformably on the pre-Cambrian	Lake Louise, 105
						Fairview, 600 +

The numerals indicate the thickness of each formation in feet. The only horizons definitely correlated by strongly marked and similar faunas are the Pioche and Mount Whyte; Spence and Stephen; Notch Peak, St. Charles, and Sherbrooke.

There are many partial sections that supplement various portions of the three great sections. These I wish to utilize in connection with the study of the Cambrian trilobites of the Cordilleran area, as our present knowledge of the vertical range and distribution of the trilobites is too limited and inaccurate to be more than of value in general and broad correlations. It is also true that many of the great limestone beds now considered as almost without fossils will be found in their extension away from the three great sections to contain a well-marked fauna.

In closing this brief review, I wish to call attention to the close relationship between the great Cambrian section of the Province of Shantung, China, and the Cordilleran sections. The thickness of the strata is very much less, but the general character and stratigraphic succession of the Cambrian faunas is very much the same. This will be discussed in the introduction to a paper on the Cambrian faunas of China, upon which I am now at work.


Longitude West 190°20' from Greenwich
TATOW KNOB
(8430)
WHIRLWIND VALLEY
Swasey Spring
SWASEY PEAK
(9675)
Sinbad Canyon
Antelope Spring
Wheeler Amphitheater
Dome Canyon
39°20'N
39°20'N
HOWELL PEAK
ROAD TO



HOUSE RANGE, MILLARD COUNTY, UTAH

CENTRAL PORTION

Scale

1 ½ 0 1 2 3 4 5 Miles

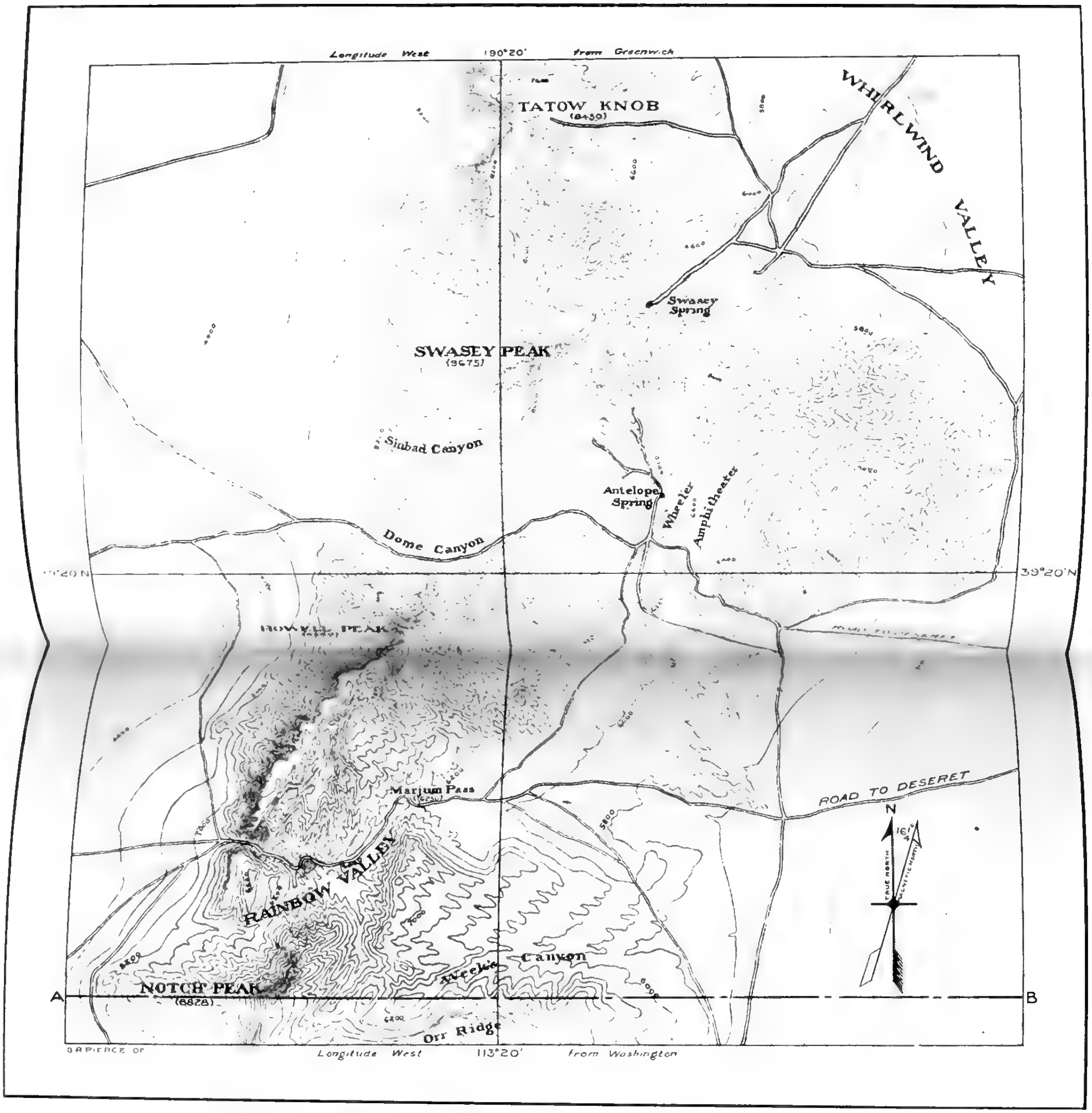
1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 200ft

Datum is mean sea level

Contours below "A-B" have been added to Map to show approximate relations of Notch Peak and Orr Ridge to the rest of the range

TOPOGRAPHY BY W. D. JOHNSON, 1901



HOUSE RANGE, MILLARD COUNTY, UTAH

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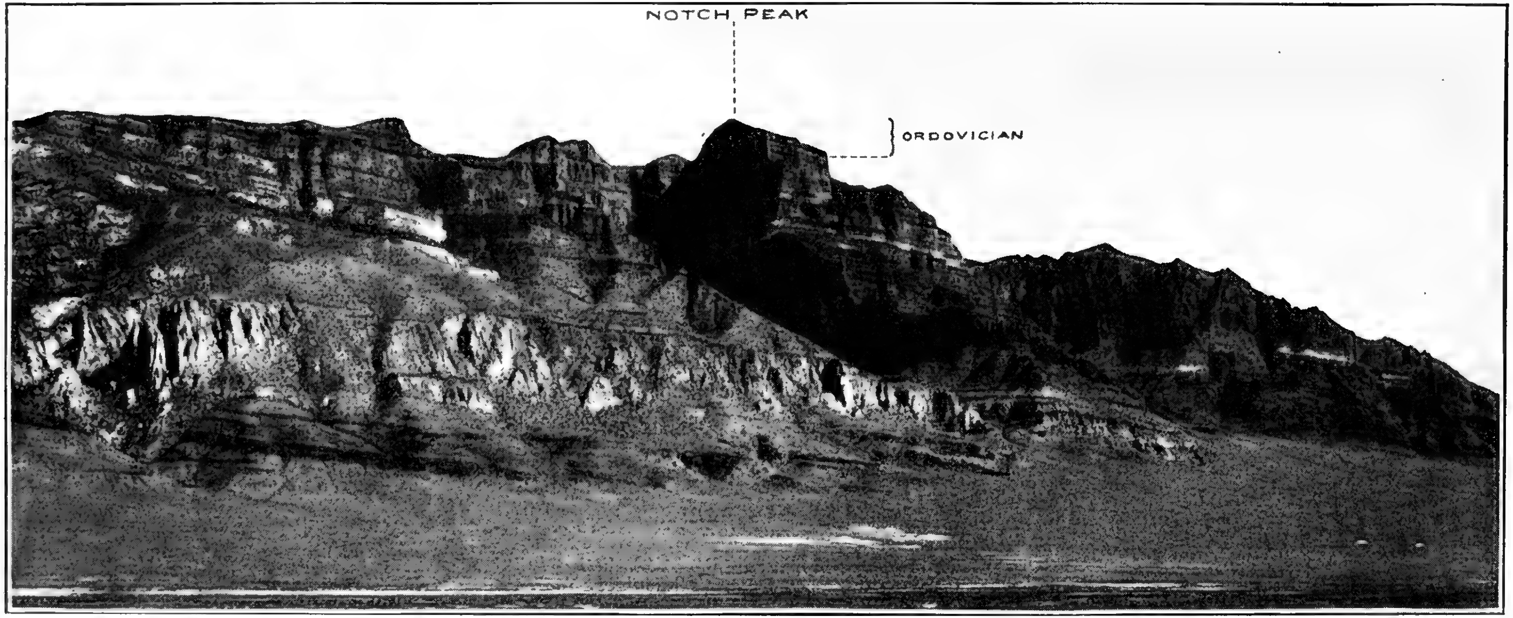


WEST FACE OF NOTCH PEAK, HOUSE RANGE, SOUTH OF MARJUM PASS, UTAH

The summit of Notch Peak is capped with Ordovician limestone, and an intrusive mass of granite porphyry is intruded into the Cambrian beds on the north slope of the peak (left side). The Notch Peak formation is beautifully shown in the 1,400-foot cliff exposed in the dark canyon just beneath the peak. (See Plate 15, Figure 1, for opposite side of Notch Peak.)

HOUSE RANGE SECTION

In order to locate the various points referred to, the accompanying map has been prepared, under the direction of Mr. L. D. Burling, from a manuscript topographic map made by Mr. W. D. Johnson of the U. S. Geological Survey (see plate 13).

LOCALITY.—West and east of Antelope Springs and east-southeast and south of Marjum Pass, House Range, Millard County, Utah. Sawtooth Range is a name given locally to the House Range south of Marjum Pass.

The section begins at the top, 285 feet below the summit of Notch Peak, the highest point (8,828 feet) on the House Range south of Marjum Pass.

The top of the peak is formed of 285 feet of Ordovician limestone, which is a banded, thin-bedded, bluish gray and purplish limestone containing near the top a distinct fauna:

Obolus (Westonia) notchensis Walcott [1908*d*, p. 69].
Eoorthis coloradoensis (Meek) [1870, p. 425].
Raphistoma sp., etc.

The strike of the upper beds is north 20° east (magnetic); dip, 12° south.

The line of the section extends down the northeast slope of Notch Peak and thence to a high ridge east of the area of eruptive granite on the northwest slope of Notch Peak; thence north to Marjum Pass. It is then carried on the line of the upper beds of the Wheeler formation to a point southeast of Antelope Springs; thence west to Dome Pass and (on the north side of Dome Canyon) to the Lower Cambrian quartzitic sandstones that pass beneath the quaternary of the White Valley at the western foot of the House Range.

ORDOVICIAN

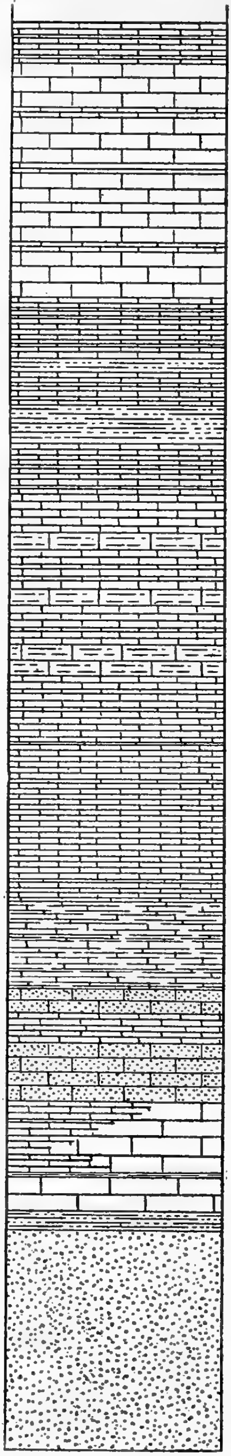
	Feet
Limestone resting conformably on the Cambrian....................	285

UPPER CAMBRIAN

NOTCH PEAK FORMATION:

The Notch Peak formation [Walcott, 1908*a*, p. 9] is exposed on the east and southeast slopes and ridges of Notch Peak.

	Feet
1*a*. Gray, arenaceous limestone in thick layers and bands of thin layers. Irregular nodules and thin layers of dark gray chert, weathering dark brown, occur at irregular intervals for 350 feet below the summit. Thin, cherty layers, one-half to one-eighth inch thick, also occur occasionally below............	640



		Feet	Meters	
Ord.		250	76	Thin-bedded limestone
Upper Cambrian	Notch Peak limestone	1490	451	Massive bedded, arenaceous limestone with a few thin beds
Upper Cambrian	Orr limestones and shale	375 84 206 235 925	114 26 63 72 282	Thin bedded limestones with two bands of arenaceous shale
Middle Cambrian	Weeks limestone	1390	424	Thin bedded and shaly limestones
Middle Cambrian	Marjum limestone	1102	336	Thin bedded limestones
Middle Cambrian	Wheeler shales	570	174	Calcareous shales
Middle Cambrian	Swasey limestone	152 188	46 57	Arenaceous limestone above, with thin bedded limestone below
Middle Cambrian	Dome limestone	355	108	Massive bedded, arenaceous limestone
Middle Cambrian	Howell limestone	435	133	Thick and thin bedded limestone
Middle Cambrian	Spence shale	<20	6	Argillaceous shale
Middle Cambrian	Langston (?) limestone	205	62	Bluish gray arenaceous limestone
Middle Cambrian	Pioche shale	125	38	Arenaceous shale
Lower Cambrian	Prospect Mountain sandstones	1375	419	Brown quartzitic sandstone

FIG. 6.—House Range Section.

NOTCH PEAK FORMATION (continued):

	Feet
1*a* (continued):	
Fauna:	
Lingulella isse (Walcott) [1905, p. 330].	
Dicellocephalus ? sp. ?	
A drift boulder found 2.5 miles from the peak, and on its eastern drainage slope, and similar in its lithological appearance to the gray, arenaceous limestone of this horizon, contained the following fossils:	
Eoorthis coloradoensis (Meek) [1870, p. 425].	
Schizambon typicalis Walcott [1884, p. 70].	
Agraulos.	
Solenopleura.	
Illænurus.	
Another drift boulder was found near this with slightly different fauna.	
Crepicephalus.	
Ptychoparia.	
1*b*. Shaly, dark gray to bluish gray, arenaceous limestone, with small dark concretions in some layers	90
No fossils observed.	
1*c*. Gray, siliceous limestone in layers of varying thickness, 4 inches to 2 feet, banded with dark cherty layers and purer arenaceous limestone. The chert takes the form of flattened nodules and very thin irregular layers	340
1*d*. Shaly and thin-bedded, bluish gray, arenaceous limestone	65
1*e*. Gray, siliceous limestone in layers 2 inches to 2 feet thick. In the lower part of this limestone, where it is not metamorphosed, it is dove-colored and in layers 6 inches to 3 feet thick. There are occasional occurrences of gray, cherty matter, as flattened nodules, and thin layers that weather a dark brown	355
Fauna (about 120 to 150 feet from the base):	
Obolus tetonensis leda Walcott [1908*d*, p. 63].	
Fragments of the free cheek of a trilobite.	
Total of Notch Peak formation	1,490

ORR FORMATION:

The section is carried along the strike of the exposed strata two miles east to the west side of Orr Ridge, where the rocks of the Orr formation [Walcott, 1908*a*, p. 10] are unmetamorphosed and present the following characters:

	Feet
1*a*. Bluish gray to gray, compact limestone in layers 1 inch to 2 feet thick. On weathering the thicker layers break down into thin, irregular layers, which form a talus of angular fragments	375

ORR FORMATION (continued):

	Feet
1a (continued):	
Fauna: Fragments of trilobites.	
1b. Sandy and siliceous, bluish and drab-colored shales, with interbedded bands of dark, bluish gray limestone 6 inches to 2 feet thick	84

Fauna:
Section of crinoid column.
Lingulella manticula (White) [1874, p. 9].
Lingulella isse (Walcott) [1905, p. 330].
Obolus rotundatus (Walcott) [1898, p. 415].
Ptychaspis.
Anomocare.

1c. Lead-colored, finely oölitic, and arenaceous limestone in layers 4 inches to 2 feet thick that are obscurely banded by thin strips of light and dark gray color........................	91

Fauna:
Fragments of trilobites.

1d. Bluish gray, compact limestone in layers 2 inches to 4 feet thick that break down into irregular, thin layers on weathering...	115

Fauna (near base):
Fragments of trilobites.
Linnarssonella modesta Walcott [1908*d*, p. 90].
Linnarssonella nitens Walcott [1908*d*, p. 91].
Solenopleura.

1e. Dirty brown and bluish black, arenaceous shales, with thin nodules of gray, fossiliferous limestone in some horizons; also a few layers of bluish gray limestone 4 inches to 8 inches thick	235

Fauna (near the top):
Linnarssonella modesta Walcott [1908*d*, p. 90].
Lingulella isse (Walcott) [1905, p. 330].
Ptychoparia?
Solenopleura.

Fauna (near the base):
Micromitra (*Paterina*) *crenistria ?* (Walcott) [1897, p. 713].
Obolus mcconnelli pelias (Walcott) [1905, p. 330].
Lingulella desiderata (Walcott) [1898, p. 399].
Lingulella isse (Walcott) [1905, p. 330].
Linnarsonella transversa Walcott [1908*d*, p. 92].
Agnostus.
Crepicephalus.

2a. Gray, slightly arenaceous limestone in layers 2 to 6 feet thick, weathering lead gray. (Cliff-forming beds.)..............	590

ORR FORMATION (continued):

	Feet
2a (continued):	
Fauna (at base):	
Lingulella desiderata (Walcott) [1898, p. 399].	
Acrotreta idahoensis Walcott [1902, p. 587].	
Crepicephalus texanus (Shumard) [1861, p. 218].	
Bathyuriscus.	
Illænurus ??	
Fauna (275 feet above base):	
Agraulos.	
Crepicephalus texanus (Shumard) [1861, p. 218].	
Illænurus.	
2b. Gray limestone and dark gray chert in alternating layers, one-half to 2 inches thick. The irregular cherty layers weather in relief as dark brown bands and the limestone as lead-colored bands, which give a very characteristic banded appearance to the cliff	170
2c. Gray, arenaceous limestone in massive beds that usually break up, on weathering, into irregular layers one-fourth to 4 inches thick. The upper 20 feet form a more massive, solid bed than the layers below	165
Fauna:	
Traces of trilobites and brachiopods.	
Total of Orr formation	1,825
Total Upper Cambrian	3,315

MIDDLE CAMBRIAN

WEEKS FORMATION:

The Weeks formation [Walcott, 1908*a*, p. 10] is exposed at Weeks Canyon (see pl. 13) from beneath the massive limestone on the south side of the canyon to the top of the cliffs on the south side of Marjum Pass. Average dip, 12°; strike, north 20° east (magnetic).

	Feet
1a. Thin-bedded limestones in layers 1 to 4 inches thick. The limestone is mainly fine-grained, dark gray, weathering lead-colored, except on bedding planes, where it is usually more or less pinkish colored	245
Fauna:	
Fragments of trilobites and brachiopods of the fauna in shaly limestone in 1*b*.	
1b. Shaly limestone, usually dark gray, with pinkish tinge in some layers and on the surfaces; sometimes buff yellow on weathering. The shales vary from one-eighth to 1 inch thick. This is a marked band in some sections and is arbitrarily separated from the shaly beds below	285

WEEKS FORMATION (continued):

	Feet
1b (continued):	
Fauna:	
The fauna ranges through about 100 feet of the lower portion of this division.	
Obolus (*Fordinia*) *perfectus* Walcott [1908*d*, p. 65].	
Agnostus (2 species).	
Ptychoparia.	
Crepicephalus texanus (Shumard) [1861, p. 218].	
Anomocare.	
Bathyuriscus.	
Asaphiscus minor, new species.	
The fauna is much like that of *1c*. Its most characteristic trilobite is *Asaphiscus minor,* new species.	
1c. Shaly, bluish gray to dark gray limestone in layers one-eighth to 1 inch thick, with occasional layers 2 to 6 inches thick; 25 feet from the top a band of layers of arenaceous, dirty gray, finely oölitic limestone, 3 feet thick, occurs, and a second similar band 38 feet below	170
Fauna:	
The fauna is rich in numbers of specimens and quite varied. The best specimens occur on the surface of the shaly layers in the lower portion of the division.	
Lingulella isse (Walcott) [1905, p. 330].	
Obolus (*Fordinia*) *perfectus* Walcott [1908*d*, p. 65].	
Acrotreta ophirensis Walcott [1902, p. 591].	
Acrotreta ophirensis descendens Walcott [1908*d*, p. 94].	
Hyolithes.	
Agnostus (several species).	
Ptychoparia (several species).	
Crepicephalus texanus (Shumard) [1861, p. 218].	
Solenopleura.	
Asaphiscus minor, new species.	
1d. Reddish tinted, more or less arenaceous, shaly limestone	30
Fauna:	
Same as *1c*, but not abundant.	
1e. Shaly, bluish gray to dark gray limestone, similar to *1c*	270
Fauna:	
Same as that of *1c*.	
1f. Evenly bedded, bluish gray to dark gray, fine-grained limestone, in layers 2 to 16 inches thick, with shaly limestone partings	330
Fauna:	
A few traces of *Agnostus* and *Ptychoparia* similar to those above.	
1g. Calcareous shales with thin layers of limestone	60
Total thickness of Weeks formation	1,390

Fig. 1. VIEW FROM THE NORTHEAST OF THE EAS

The rounded hills of the foreground are eroded in the Wheeler
Cambrian limestones of the Weeks, Orr, and Notch Peak formations,
by 285 feet of Ordovician limestone.

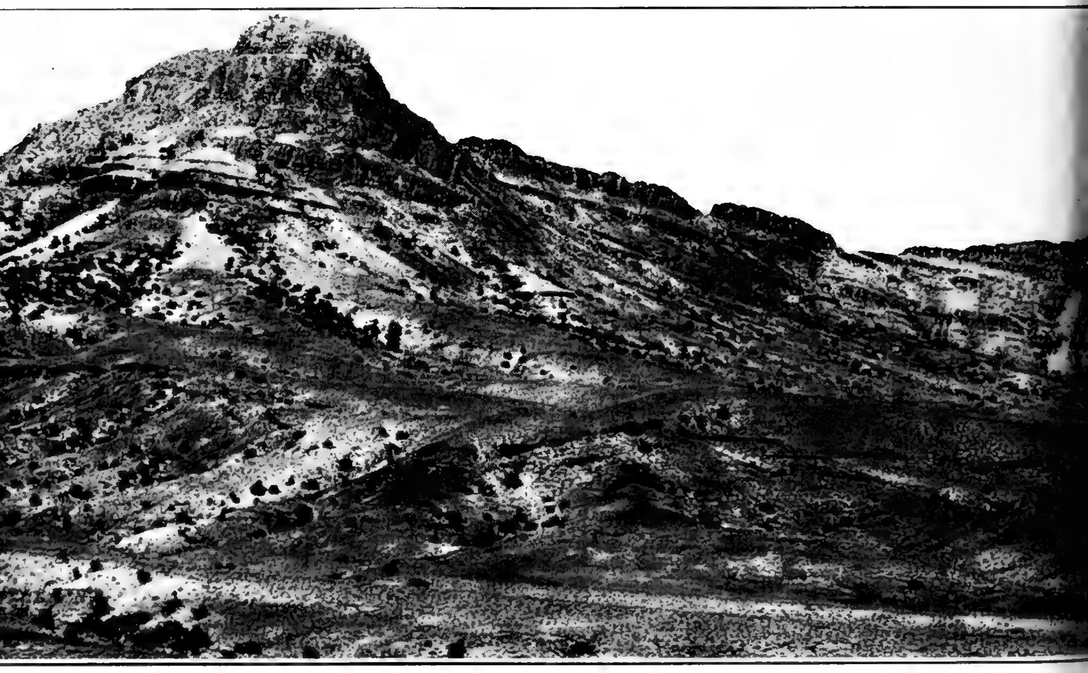
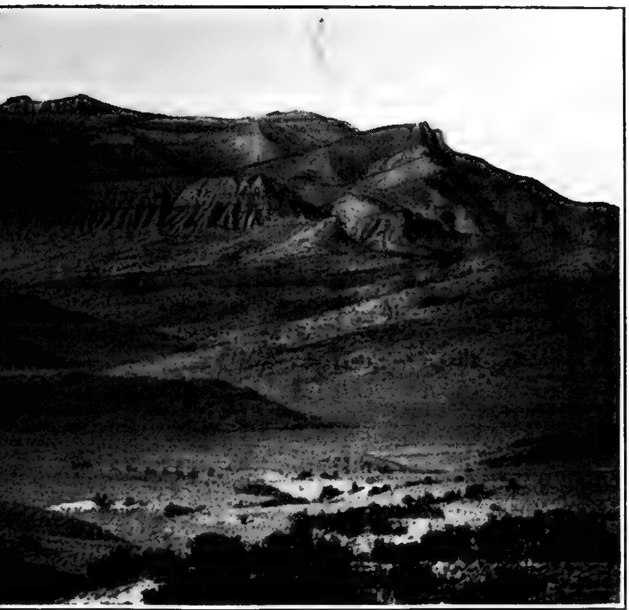


Fig. 2. PANORAMIC VIEW OF RIDG

Looking across Wheeler Amphitheater, House Range. The Wheeler shale extends to the base ot the low f
re on the slopes of the mountain on the left side of the illustration.



HOUSE RANGE SOUTH OF MARJUM PASS, UTAH

n limestone forms the long horizontal cliff, and back of this the
ntinue on up to near the summit of Notch Peak, which is capped

EAST OF ANTELOPE SPRINGS

rjum formation to the summit of the ridge. The best known fossil localities in the Marjum formation

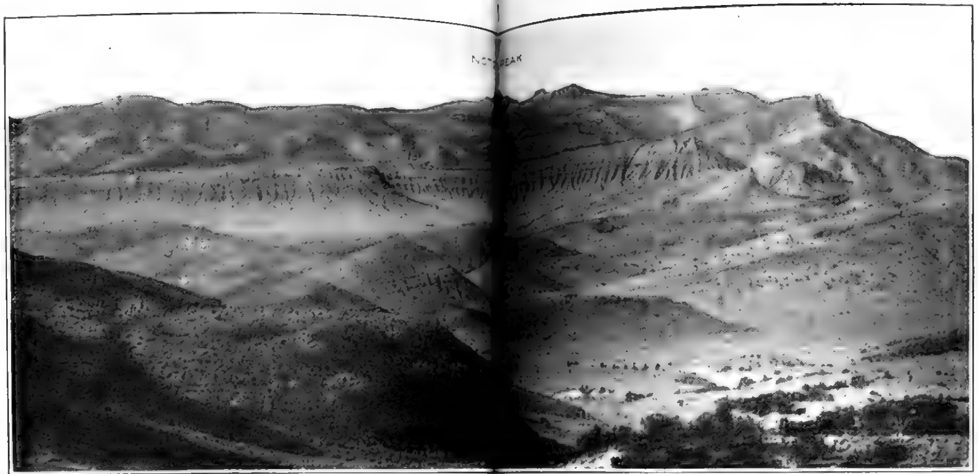


Fig. 1. VIEW FROM THE NORTHEAST OF THE EASTE[illegible] OF THE HOUSE RANGE SOUTH OF MARJUM PASS, UTAH

The rounded hills of the foreground are eroded in the Wheeler sha[illegible] Marjum limestone forms the long horizontal cliff, and back of this the Cambrian limestones of the Weeks, Orr, and Notch Peak formations, [illegible] thick, continue on up to near the summit of Notch Peak, which is capped by 285 feet of Ordovician limestone.

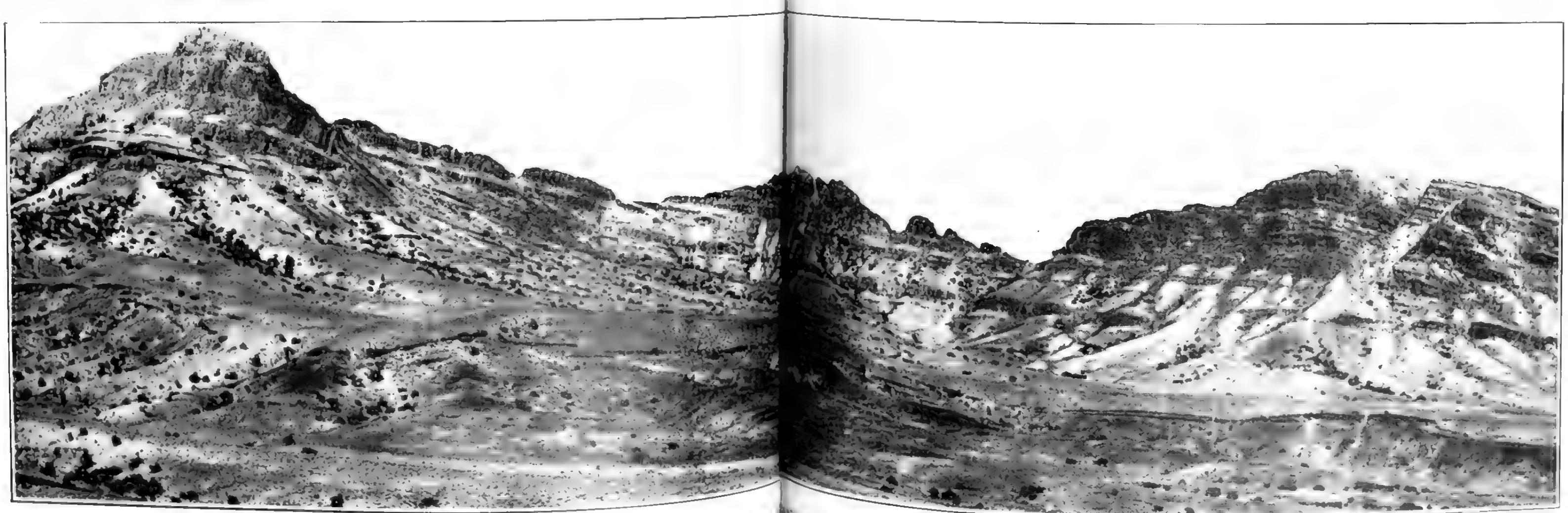


Fig. 2. PANORAMIC VIEW OF [illegible]THEAST OF ANTELOPE SPRINGS

Looking across Wheeler Amphitheater, House Range. The Wheeler shale extends to the base of the low f[illegible] the Marjum formation to the summit of the ridge. The best known fossil localities in the Marjum formation are on the slopes of the mountain on the left side of the illustration.

MARJUM FORMATION:

The Marjum formation [Walcott, 1908*a*, p. 10] is exposed in the cliffs southeast of Marjum Pass and in the ridge east of Wheeler Amphitheater.

Feet

1*a*. Gray, more or less thin-bedded limestone that weathers to a dark lead-gray color and breaks down into angular fragments one-half to 2 inches thick.
Flattened cherty nodules and thin, irregular cherty layers occur at intervals 305

Fauna (in upper 100 feet):
Obolus mcconnelli pelias (Walcott) [1905, p. 330].
Obolus (Fordinia) gilberti Walcott [1908*d*, p. 65].
Obolus (Fordinia) perfectus Walcott [1908*d*, p. 65].
Acrotreta bellatula Walcott [1908*d*, p. 93].
Acrotreta marjumensis Walcott [1908*d*, p. 94].
Acrotreta cf. *sagittalis* Salter [1866, p. 285].
Agnostus (4 species).

Fauna (central portion):
Micromitra sculptilis Meek [1873, p. 479].
Lingulella arguta (Walcott) [1898, p. 396].
Dicellomus prolificus Walcott [1908*d*, p. 77].
Acrotreta attenuata Meek [1873, p. 463].
Acrotreta bellatula Walcott [1908*d*, p. 93].
Agnostus.
Ptychoparia.
Anomocare.

Fauna (near base):
Micromitra (Iphidella) pannula ophirensis (Walcott) [1905, p. 306].
Obolus mcconnelli pelias (Walcott) [1905, p. 330].
Obolus rotundatus (Walcott) [1898, p. 415].
Hyolithes.
Ptychoparia.
Anomocare.

1*b*. Alternating bands of dark, blue-gray, compact limestone in massive layers that break up into thin irregular layers; and gray arenaceous limestone in layers 1 to 8 inches thick.

	Feet	
1. Gray limestone	35	
2. Blue-gray limestone	7	
3. Gray arenaceous limestone........................	95	
4. Blue-gray limestone	12	
5. Gray arenaceous limestone........................	90	
6. Blue-gray limestone	8	
	——	247

Fauna:
Ptychoparia, sp. undt.

1*c*. Dark and light-gray, thin-bedded limestone, more or less arenaceous 250

MARJUM FORMATION (continued):

1*c* (continued): Feet

Fauna (near top):
Acrotreta pyxidicula White [1874, p. 9].
Agnostus.
Ptychoparia like *P. kingi* (Meek) [1870, p. 63].

Fauna (in central portion, though ranging through 100 to 150 feet of the thin-bedded shaly limestone):
Obolus mcconnelli pelias (Walcott) [1905, p. 330].
Lingulella arguta (Walcott) [1898, p. 396].
Acrothele subsidua (White) [1874, p. 6].
Acrotreta ophirensis ? Walcott [1902, p. 591].
Eoorthis thyone Walcott [1908*d*, p. 105].
Nisusia (Jamesella) nautes (Walcott) [1905, p. 283].
Nisusia (Jamesella) spencei (Walcott) [1905, p. 285].
Hyolithes.
Agnostus (2 species).
Ptychoparia (3 species).
Solenopleura.
Owenella typa, new genus and new species.
Neolenus inflatus Walcott [1908*b*, p. 30].
Neolenus intermedius Walcott [1908*b*, p. 34].
Neolenus intermedius pugio Walcott [1908*b*, p. 35].
Neolenus superbus Walcott [1908*b*, p. 36].
Ogygopsis?

1*d*. Gray, shaly limestone, passing below into shales, interbedded in the shaly limestone, and at 75 feet from the top into drab argillaceous shales 105

Fauna:
Micromitra (Iphidella) pannula ophirensis (Walcott) [1905, p. 306].
Micromitra sculptilis Meek [1873, p. 479].
Obolus mcconnelli pelias (Walcott) [1905, p. 330].
Obolus rotundatus (Walcott) [1898, p. 415].
Lingulella arguta (Walcott) [1898, p. 396].
Acrotreta attenuata Meek [1873, p. 463].
Acrotreta ophirensis Walcott [1902, p. 591].
Acrothele subsidua (White) [1874, p. 6].
Acrothele subsidua lævis, new variety.
Eoorthis remnicha (N. H. Winchell) [1886, p. 317].
Eoorthis thyone Walcott [1908*d*, p. 105].
Syntrophia unxia Walcott [1908*d*, p. 105].
Agnostus (3 species).
Ptychoparia.
Owenella typa, new genus and new species.
Neolenus inflatus Walcott [1908*b*, p. 30].
Neolenus intermedius Walcott [1908*b*, p. 34].
Neolenus superbus Walcott [1908*b*, p. 36].
Ogygopsis?

MARJUM FORMATION (continued):

Feet

1e. Dark, bluish gray limestone in thick beds that break up on weathering into thin, irregular layers one-half to 2 inches thick 195

Fauna:
Linnarssonella sp.
Agnostus.
Ptychoparia.
Ogygopsis.

Total thickness of Marjum formation................ 1,102

WHEELER FORMATION:

The Wheeler formation [Walcott, 1908*a,* p. 10] is exposed at Marjum Pass, but the type locality is in Wheeler Amphitheater, southeast of Antelope Springs. The section was measured south from the ridge south of the lower springs of Antelope Springs.

Feet

1. Alternating bands of thin, shaly limestone and calcareous shale, with shale gradually increasing and predominating toward the lower portion. At 405 feet from top a band of blue-gray, hard limestone, in layers one-eighth to 2 inches thick, occurs. At 473 feet another band, and below an occasional thin layer.. 570

Fauna:
Acrothele subsidua (White) [1874, p. 6].
Agnostus bidens Meek [1873, p. 463].
Asaphiscus wheeleri Meek [1873, p. 485].
Ptychoparia kingi (Meek) [1870, p. 63].

These species occur in great numbers at 230 feet to 350 feet from the base. Many hundred trilobites, entire and backed by "cone-in-cone," have been picked up on the surface of the clay, resulting from the disintegration of the shales.

Obolus mcconnelli pelias Walcott and *Acrotreta attenuata* Meek occur more rarely.

SWASEY FORMATION:

The section of the Swasey formation [Walcott, 1908*a,* p. 11] is exposed on the southwest ridge of Swasey Peak.

Feet

1a. Oölitic and arenaceous limestone in massive layers near the top. Below, dark bluish gray limestone is occasionally interbedded, and gradually it becomes the principal rock; it breaks up on weathering into irregular, shaly layers one-half to 3 inches thick.. 152

Fauna (near the top):
Platyceras.
Zacanthoides.

Fauna (near the base):
Scenella.
Zacanthoides.
Ptychoparia.
Dorypyge.

SWASEY FORMATION (continued):

		Feet
1*b*.	Drab and reddish argillaceous shales, with interbedded, thin layers of fossiliferous limestone	63
1*c*.	Dark, bluish gray limestone in massive layers that break up into irregular, shaly layers one-fourth to 2 inches thick	17
1*d*.	Calcareous and argillaceous shales with thin layers of gray limestone	102

Fauna:

Micromitra (*Paterina*) *labradorica utahensis* (Walcott) [1905, p. 306].
Lingulella arguta (Walcott) [1898, p. 396].
Ptychoparia (2 species).

1*e*.	Bluish gray limestone in layers 4 to 10 inches thick, with numerous concretions from one-eighth to 1 inch in diameter, in a few layers	6

Fauna:

Obolus (*Westonia*) *ella* (Hall and Whitfield) [1877, p. 232].
Ptychoparia (3 species).

Total of Swasey formation	340

DOME LIMESTONE:

The section of the Dome limestone [Walcott, 1908*a*, p. 11] is exposed in the central portion of Dome Canyon and adjoining cliffs.

	Feet
Massive bedded, cliff-forming, gray, siliceous limestone, with small specks of calcite. One hundred feet from the top, and for 50 feet below, occasional layers 15 inches to 2 feet thick, of brownish yellow, arenaceous limestone, occur	355

HOWELL FORMATION:

The section of the Howell formation [Walcott, 1908*a*, p. 11] is exposed on the west face of the House Range at Howell Mountain.

		Feet
1*a*.	Bluish black limestone in massive layers that break up on weathering into irregular, thin layers	50

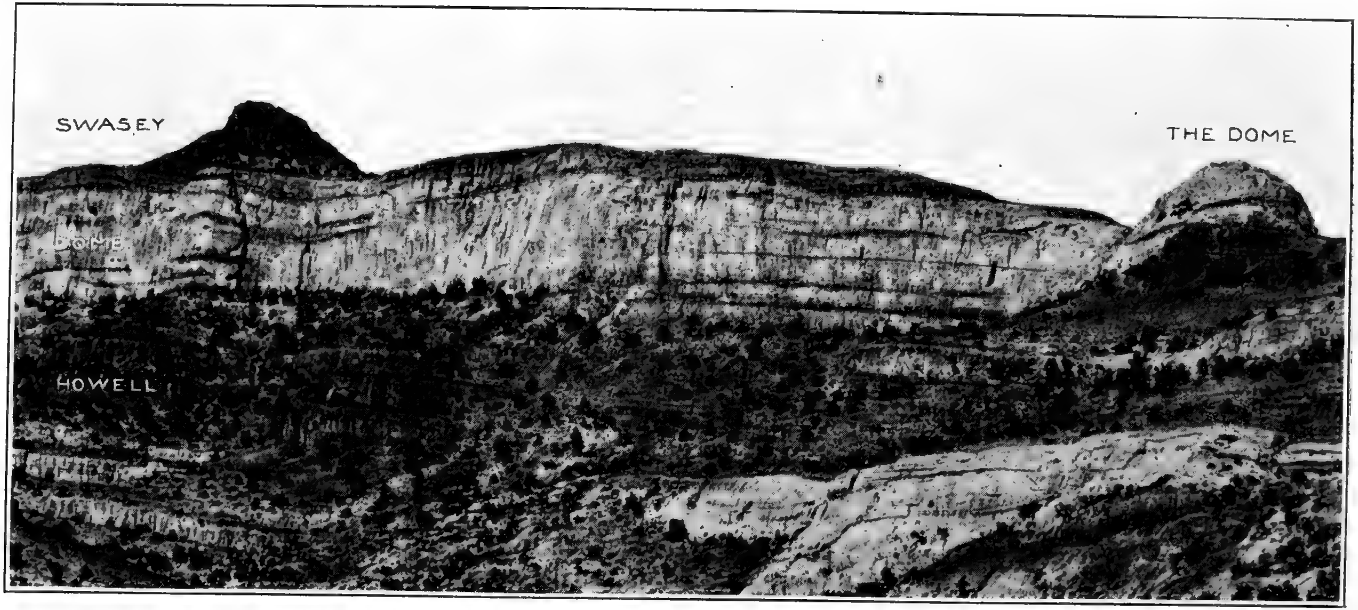
Fauna (in shaly bed at top of 1*a*):

Micromitra (*Iphidella*) *pannula* (White) [1874, p. 6].
Acrotreta cf. *ophirensis* Walcott [1902, p. 591].
Ptychoparia.

1*b*.	Gray, siliceous limestone	8
1*c*.	Bluish black limestone, similar to 1*a*	105
1*d*.	Pinkish colored, argillaceous shale with interbedded, thin layers of limestone	10

Fauna:

Micromitra (*Iphidella*) *pannula* (White) [1874, p. 6].
Obolus (*Westonia*) *ella* (Hall and Whitfield) [1877, p. 232].
Acrotreta cf. *ophirensis* Walcott [1902, p. 591].
Scenella.
Hyolithes.
Zacanthoides.
Bathyuriscus.



VIEW OF THE NORTH SIDE OF DOME CANYON BELOW DOME PASS, HOUSE RANGE

The dark Swasey limestone forms the dark peak at the left. This rests on the light gray cliff of Dome limestone, below which the Howell formation breaks down. A mass of the Dome limestone has been displaced in the foreground by a fault between it and the cliff. The dome from which the canyon formation takes its name is shown at the right.

HOWELL FORMATION (continued):

	Feet
1*e*. Gray, siliceous limestone in layers 2 to 10 inches thick........	70
1*f*. Bluish black limestone in massive layers, breaking up into thin layers on weathering....................................	102

Fauna:
Ptychoparia.
Bathyuriscus.

1*g*. Gray, siliceous limestone in thick beds........................	90
Total of Howell formation.........................	435

Spence shale:

The Spence shale [Walcott, 1908*a*, p. 8] is exposed on the east side of Dome Canyon a little above where it bends to the westward.

	Feet
1. Pinkish, argillaceous shale....................................	20

Fauna:
Micromitra (*Iphidella*) *pannula* (White) [1874, p. 6].
Obolus (*Westonia*) *ella* (Hall and Whitfield) [1877, p. 232].
Lingulella dubia (Walcott) [1898, p. 401].
Acrothele subsidua (White) [1874, p. 6].
Hyolithes billingsi Walcott [1886, p. 134].
Ptychoparia piochensis Walcott [1886, p. 201].
Ptychoparia sp.
Zacanthoides typicalis (Walcott) [1886, p. 183].
Bathyuriscus productus (Hall and Whitfield) [1877, p. 244].

LANGSTON (?) FORMATION:

The section of the beds which are doubtfully placed in the Langston formation [Walcott, 1908*a*, p. 8] was measured at the same locality as the Spence shale.

	Feet
1*a*. Massive bedded, bluish gray, arenaceous limestone, with irregular partings of buff-colored arenaceous limestone. The latter penetrates the layers of limestone in the most irregular manner and frequently surrounds small, irregular nodules of the bluish gray limestone..............................	170

Fauna:
Billingsella, sp. undt.
Platyceras.
Hyolithes.
Leperditia.
Ptychoparia.
Zacanthoides.
Dorypyge?

1*b*. Brown, buff weathering, arenaceous limestone in thick layers; almost sandstone in places..................................	35
Total of Langston (?) formation....................	205
Total Middle Cambrian............................	4,417

LOWER CAMBRIAN

PIOCHE FORMATION:

The Pioche formation [Walcott, 1908*a*, p. 11] is exposed at the westward bend of Dome Canyon.

	Feet
1. Arenaceous and siliceous shaly layers, with some thicker layers of quartzitic sandstone	125

Fauna:
Annelid trails.
Trilobite tracks (*Cruziana*).

Southwest of Pioche, Nevada, on the Panaca Road, this formation contains the following fauna:

Eocystites ? longidactylus Walcott [1886, p. 94].
Obolus (*Westonia*) *ella* (Hall and Whitefield) [1877, p. 232].
Micromitra (*Iphidella*) *pannula* (White) [1874, p. 6].
Acrothele subsidua (White) [1874, p. 6].
Acrothele subsidua hera Walcott [1908*d*, p. 87].
Acrothele spurri Walcott [1908*d*, p. 86].
Acrotreta primæva Walcott [1902, p. 593].
Billingsella highlandensis (Walcott) [1886, p. 119].
Hyolithes billingsi Walcott [1886, p. 134].
Olenellus gilberti Meek [1874, p. 7].
Zacanthoides levis (Walcott) [1886, p. 187].
Crepicephalus augusta Walcott [1886, p. 208].
Crepicephalus liliana Walcott [1886, p. 207].

PROSPECT MOUNTAIN FORMATION:[1]

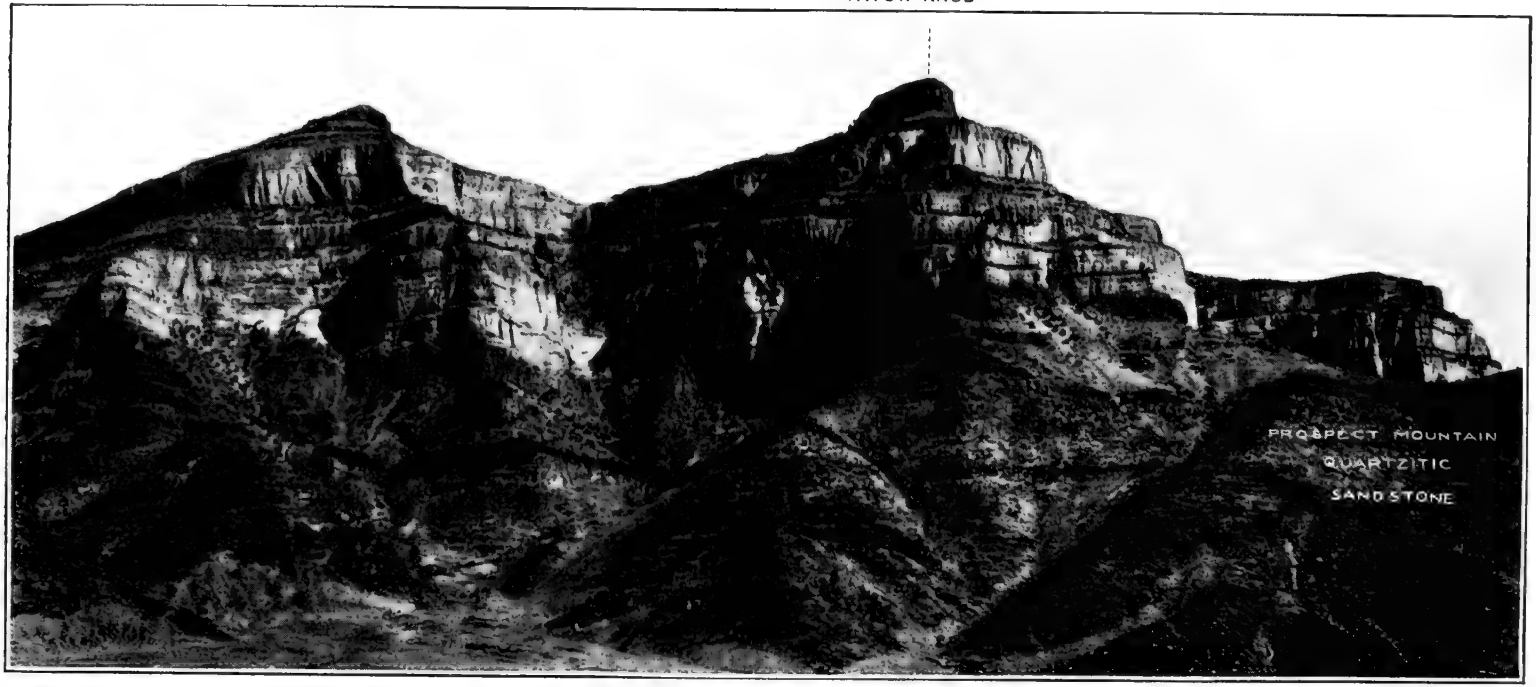
The Prospect Mountain formation [see Walcott, 1908*a*, p. 12] is exposed on the west slope and foothills of the House Range north and south of Dome Canyon.

	Feet
1. Gray and brownish quartzitic sandstone in layers 4 inches to three feet in thickness	1,375+
Total Lower Cambrian	1,500+

RÉSUMÉ, HOUSE RANGE SECTION

UPPER CAMBRIAN:	Feet	Feet
Notch Peak formation	1,490	
Orr formation	1,825	
Total		3,315

[1] As the result of conference with Mr. Arnold Hague, the following formation names are given for formations in the Eureka section (see Walcott, 1884, p. 284): Eldorado limestone replaces Prospect Mountain limestone; Dunderberg shale replaces Hamburgh shale, the name Hamburgh being retained for the Hamburgh limestone.



WEST FACE OF HOUSE RANGE BENEATH TATOW KNOB

The Prospect Mountain formation forms the lowest beds, and above, the Pioche shale of the Lower Cambrian, then in turn the limestones of the Langston and Howell formations separated by a narrow band of Spence shale, and above, the Dome and Swasey limestones. Tatow is a word of Indian derivation signifying "nipple", and the topographic feature to which it refers is locally known as "Mollie's Nipple."

RÉSUMÉ, HOUSE RANGE SECTION (continued):

		Feet
MIDDLE CAMBRIAN:		
Weeks formation	1,390	
Marjum formation	1,102	
Wheeler formation	570	
Swasey formation	340	
Dome formation	355	
Howell formation	435	
Spence shale	20	
Langston (?) formation	205	
Total		4,417
LOWER CAMBRIAN:		
Pioche formation	125	
Prospect Mountain formation (estimated)	1,375+	
Total		1,500+
Total section		9,232+

WAUCOBA SPRINGS SECTION

LOCALITY.—East of Waucoba Springs, on the Saline Valley road, east of the Inyo Range, Inyo County, California.

LOWER CAMBRIAN

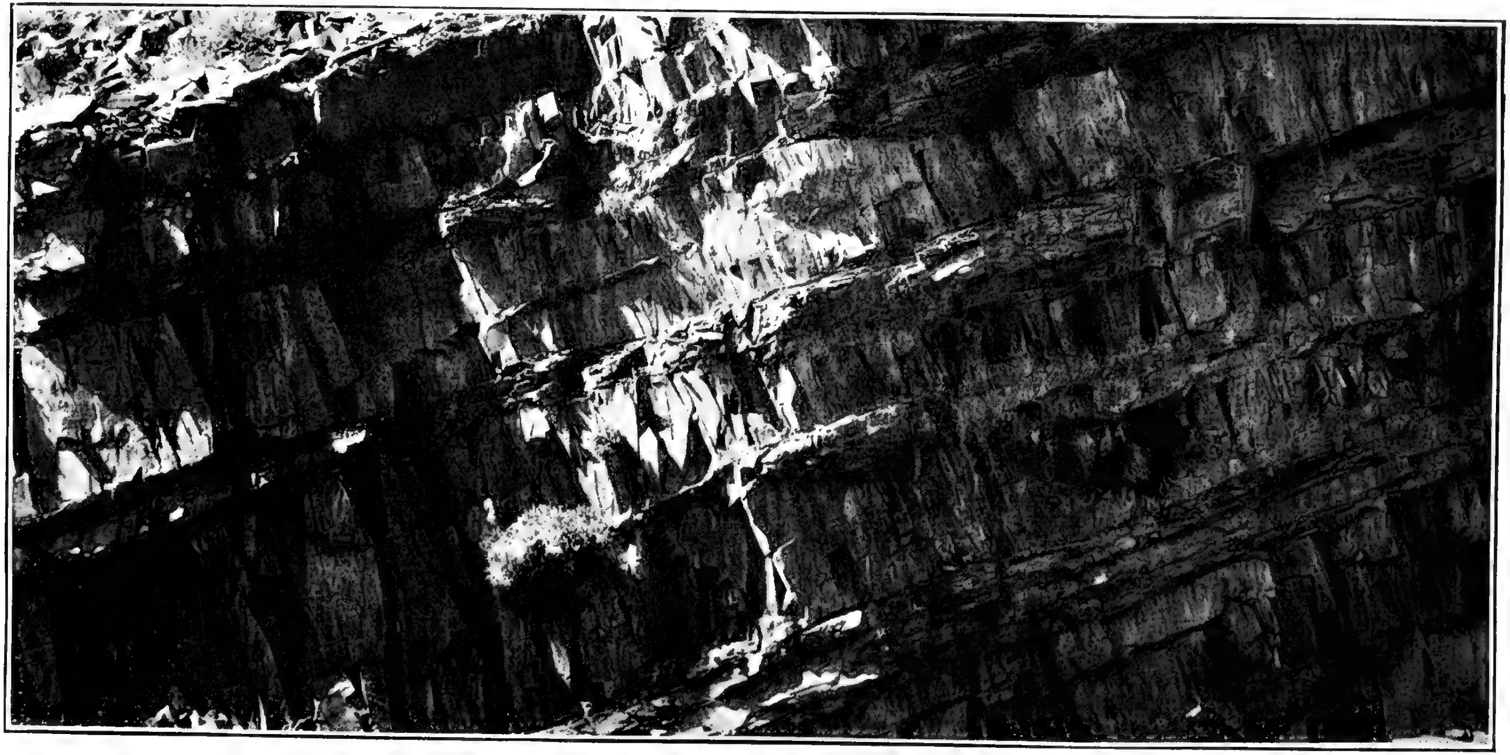
SILVER PEAK GROUP:[1]

	Feet
1a. Bluish gray, compact limestone with irregular, inosculating threads and stringers of yellowish to buff magnesian limestone. Immense numbers of dark concretions one-fourth to one inch in diameter occur in the greater proportion of the layers. The latter vary from 6 inches to 2 feet in thickness..	525
Fauna: Sections of a calcareous brachiopod and a large *Orthotheca*-like shell occur about 50 feet from the base.	
1b. Light bluish gray limestone	115
1c. Massive bedded, dark bluish gray limestone	60
1d. Lead-colored, arenaceous limestone, with layers of sandstone 1 to 2 inches thick in bands in lower portion, with a band of cross-bedded buff calcareous sandstone about 50 feet from the base. Layers of bluish gray limestone, banded dark and light gray limestone, and a few layers of brown, quartzitic sandstone occur at irregular intervals	340

[1] The name Silver Peak was first used by Mr. H. W. Turner in describing the Cambrian rocks of Esmeralda County, Nevada. American Geologist, XXIX, 1902, pp. 264–265.

SILVER PEAK GROUP (continued):

	Feet
1d (continued):	
Fauna (105 feet from the base):	
Salterella.	
Holmia weeksi, new species.	
Total of 1	1,040
2a. Dark, siliceous, indurated shales, shaly sandstone and quartzitic sandstone in alternating layers	35
Fauna:	
Annelid trails.	
Cruziana.	
2b. Buff, drab, and bluish gray arenaceous limestone alternating in layers and bands	120
2c. Gray and dirty brown sandstones, with bands of light gray quartzitic sandstones	125
2d. Gray limestone, becoming arenaceous and passing into gray and dirty brown sandstone	105
Fauna:	
Traces of fragments of trilobites on the surface of the sandstone.	
2e. Gray and dirty brown, compact sandstone in layers from 2 inches to 2 or 3 feet in thickness. In the lower portion of the strata are layers of massive bedded, gray quartzitic sandstone. Small concretions 1 to 2 millimeters in diameter are very abundant in many of the upper layers	365
2f. Hard, brown and gray, shaly sandstones, with an occasional irregular, thin layer of bluish gray limestone	155
2g. Bluish gray arenaceous limestone in thick layers	25
2h. Greenish-colored arenaceous shale	120
2i. Alternating bands of arenaceous shale and massive bedded, gray, quartzitic sandstones	430
Fauna:	
Scolithus occurs abundantly in many of the quartzitic sandstones.	
Fauna (50 feet from the top):	
Salterella.	
Olenellus (fragments).	
2j. Gray quartzitic sandstones in layers 8 inches to 3 feet in thickness, passing below 35 feet into buff to yellowish shale with greenish buff bands, with some interbedded, gray, quartzitic sandstones	485
Fauna (in quartzitic layers):	
Scolithus like *S. linearis* Haldeman [see Walcott, 1891, p. 603].	
Fauna (in lower portion):	
Obolella, sp. undt.	
Holmia rowei, new species.	



LOWER CAMBRIAN QUARTZITES

Showing vertical cleavage in massive layers and interbedded thin layers without cleavage. Soldiers Canyon, above Deep Spring Valley, White Mountain range, Inyo County, California.

SILVER PEAK GROUP (continued):

2j (continued): Feet

Near Resting Springs, in the Kingston Range, and at about this horizon, Mr. R. B. Rowe collected the following:
Billingsella highlandensis (Walcott) [1886, p. 119].
Holmia weeksi, new species.
Olenellus fremonti, new species.

2k. Gray and brownish gray quartzitic sandstones in layers 6 inches to 3 feet in thickness.................................... 790

Fauna:
Annelid trails on the surface of the layers.

Total of 2 2,755

3a. At summit a band of bluish gray limestone, with sandstones and occasional layers of thin-bedded limestone below. At 290 feet down a band of arenaceous limestone 50 feet thick occurs. Below this, brown sandstone and sandy shales, with interbedded thin layers of limestone in the lower 100 feet 650

Fauna (430 feet from the base):
Numerous fragments of *Olenellus*.

3b. Argillaceous and sandy shale, with a few thin beds of limestone 200

Fauna (160 feet from base):
Obolella, sp. undt.
Trematobolus excelsis Walcott [1908*d*, p. 80].

3c. Alternating arenaceous limestones, shales, and dirty brown sandstones that break into angular blocks and fragments... 575

Fauna (275 feet from base):
Archæocyathus is very abundant.

3d. Shaly indurated sandstones, with a few thicker layers of almost quartzitic sandstone............................... 450+

Fauna (on west slope of hill just east of the summit, where the Saline Valley wagon road passes down the slope toward Waucoba Springs):
Annelid trails.
Cruziana.
Trematobolus excelsis Walcott [1908*d*, p. 80].
Holmia rowei, new species.

Fauna (on the east side of the hill and in lower portion of 3*d*):
Archæocyathus.
Ethmophyllum gracile Meek [1868, p. 62].
Mickwitzia occidens Walcott [1908*d*, p. 54].
Obolella, sp. undt.

SILVER PEAK GROUP (continued):

3*d* (continued): Feet

Trematobolus excelsis Walcott [1908*d*, p. 80].
Hyolithes sp.
Holmia rowei, new species.

	Feet
Total of 3	1,875+
Total of section	5,670+

In this section the genus *Olenellus* is found extending through 4,900 feet of strata and its lower limit is unknown.

RÉSUMÉ, WAUCOBA SPRINGS SECTION

	Feet	Feet
1*a*. Limestone	525	
1*b*. Limestone	115	
1*c*. Limestone	60	
1*d*. Arenaceous limestone	340	
		1,040
2*a*. Shales	35	
2*b*. Arenaceous limestone	120	
2*c*. Sandstone	125	
2*d*. Arenaceous limestone	105	
2*e*. Sandstone	365	
2*f*. Sandstone	155	
2*g*. Arenaceous limestone	25	
2*h*. Shale	120	
2*i*. Shale and sandstone	430	
2*j*. Sandstone and shale	485	
2*k*. Quartzitic sandstone	790	
		2,755
3*a*. Shales, limestone, and sandstone	650	
3*b*. Shaly sandstone	200	
3*c*. Arenaceous limestone and shaly sandstone	575	
3*d*. Hard sandstones	450+	
		1,875+
Total		5,670+

BARREL SPRING SECTION

A section of Lower Cambrian strata studied by Mr. F. B. Weeks near Barrel Spring, 16 miles south of the town of Silver Peak, Nevada, is much like that east of Waucoba Springs, and has about the same fauna at various horizons in it.

	Feet
1. Massive blue mottled limestone, with 50 feet of sandy limestone in the middle of the series	737

Fauna:

Archæocyathus and allied forms occur throughout this limestone.

		Feet
2.	Sandy shales succeeded by coarse, thin, fine sandstone, with buff limestones at top	206
	Fauna (in limestone):	
	Micromitra (*Paterina*) *prospectensis* (Walcott) [1884, p. 19].	
	Nisusia (*Jamesella*) *amii* Walcott [1905, p. 252].	
	Scenella, sp.	
	Agraulos?	
	Olenellus gilberti Meek [1874, p. 7].	
3.	Green calcareous shale, arenaceous at top	390
	Fauna:	
	Archæocyathus ?	
	Kutorgina cingulata (Billings) [1861, p. 8].	
	Kutorgina perugata Walcott [1905, p. 310].	
	Siphonotreta ? dubia, new species.	
	Acrotreta claytoni Walcott [1902, p. 583].	
	Acrothele spurri ? Walcott [1908*d*, p. 86].	
	Swantonia weeksi Walcott [1905, p. 297].	
	Swantonia ? sp.	
	Stenotheca cf. *elongata* Walcott [1884, p. 23].	
	Stenotheca cf. *rugosa* (Hall) [1847, p. 306].	
	Salterella.	
	Ptychoparia sp.	
	Holmia rowei, new species.	
	Holmia weeksi, new species.	
4.	Massive blue mottled limestone	49
5.	Mainly green shales, some quartzitic shale, bands of limestone at top	580
6.	Green calcareous shale, with bands of limestone at top	564
	Fauna:	
	Salterella sp.	
	Holmia weeksi, new species.	
	Olenellus claytoni, new species.	
7.	Andesite mass	750
8.	Massive blue mottled limestone	81
9.	Green calcareous shales	238
10.	Mostly thin-bedded blue and gray shaly quartzites	904
11.	Siliceous limestones at base, then blue coral limestones	1,349
	Holmia weeksi, new species.	
	Olenellus, sp.	
12.	Massive quartzites, shaly in places	222
	Fauna:	
	Holmia rowei, new species.	
	Holmia weeksi, new species.	
13.	Siliceous buff limestones	180
	Total	6,250

Base unknown.

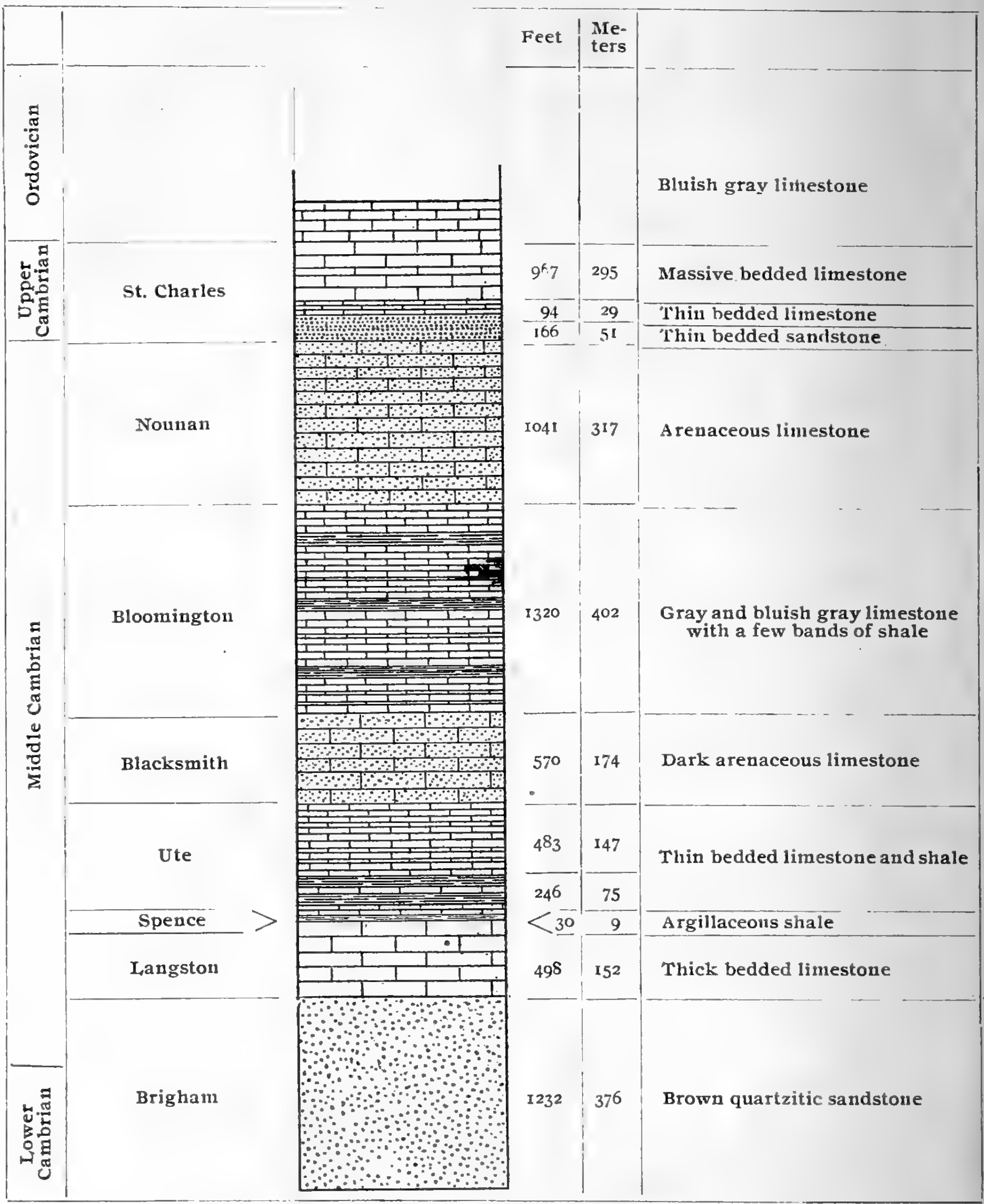


FIG. 7.—Blacksmith Fork Section

BLACKSMITH FORK SECTION

Locality.—Wasatch Mountains, between Ute and Logan Peaks, in Blacksmith Fork Canyon, east side of Cache Valley, and 12 to 16 miles east of Hyrum, in northern Utah.

This section is 230 miles northeast of the House Range section and north of the greater effect of the pre-Cambrian Uinta Mountain uplift and island. The character of the sediments derived from the Uinta area is shown by the continuation of the arenaceous deposits up to the middle of the Middle Cambrian (Acadian) time, whereas in the House Range section the arenaceous deposits cease before the Middle Cambrian fauna appears. It is not until after the Belt Mountain and Kintla (of the 49th parallel) uplifts to the north are passed that the order of sedimentation, as shown in the Mount Bosworth section, is again of the type of that of the House Range section.

ORDOVICIAN

Feet

1. Dark, bluish black and gray limestone. In the basal bed immediately above the Cambrian a fine fauna occurs. The limestone is of the same character as that of the Upper Cambrian for 190 feet below and, except for the change in the fauna, there is no break in the section. One of the characters common to the Cambrian and the superjacent Ordovician is the presence in most layers of flattened concretionary nodules and stringers from a minute size up to 6 or 8 cm. or more in diameter; the large ones rarely exceed 3 to 10 mm. in thickness.

Fauna:
Eoorthis coloradoensis (Meek) [1870, p. 425].
Syntrophia nundina Walcott [1905, p. 292].
Orthoceras.
Endoceras.
Fragments of trilobites.

UPPER CAMBRIAN

ST. CHARLES FORMATION [Walcott, 1908*a*, p. 6]:

1. Dark bluish gray and gray limestone in layers varying from 1 to 20 inches in thickness. Many of the layers are almost made up of flattened concretions varying from a minute size to 6 or 8 cm. 190

Fauna (25 feet below the top):
Lingulella manticula (White) [1874, p. 9].
Eoorthis coloradoensis (Meek) [1870, p. 425].
Syntrophia nundina Walcott [1905, p. 292].
Dicellocephalus.

ST. CHARLES FORMATION (continued):

1 (continued): Feet

Fauna (105 to 125 feet below the top):
Schizambon typicalis Walcott [1884, p. 70].
Eoorthis coloradoensis (Meek) [1870, p. 425].
Eoorthis newberryi Walcott [1908*d*, p. 105].
Syntrophia nundina Walcott [1905, p. 292].
Solenopleura.
Menocephalus.
Illænurus.

Fauna (20 to 30 feet above base):
Lingulella (Lingulepis) acuminata (Conrad) [1839, p. 64].
Eoorthis coloradoensis (Meek) [1870, p. 425].
Eoorthis newberryi Walcott [1908*d*, p. 105].
Agnostus.
Solenopleura.
Menocephalus.
Asaphus ?
Fragments of fossils occur throughout.

2a. Massive bedded, dark lead-gray, arenaceous, cliff-forming limestone, becoming thinner bedded in the lower 50 feet........ 195

2b. Massive bedded, gray, arenaceous limestone with occasional irregular cherty layers which extend down 85 feet, and just below this the dark, arenaceous limestone is almost made up of round concretions 2 to 4 mm. in diameter for a thickness of about 15 feet........ 100

2c. Gray, siliceous, and arenaceous limestone in layers one-half inch to 6 inches thick, occurring in massive bands. Light gray chert fills large and small annelid borings, and it also occurs as flattened stringers in the line of the bedding and in the layers........ 85

Fauna (34 feet from the base):
Obolus (Westonia) iphis, new species.
Lingulella desiderata (Walcott) [1898, p. 399].

2d. Massive bedded, arenaceous limestone, forming broken cliffs. A few cherty nodules occur near the top and the lower 50 feet has many irregular, oval cherty nodules and stringers of chert coincident with the bedding........ 397

Total of 2........ 777

3. Bedded, bluish gray fossilferous limestone........ 94

Fauna (upper part):
Acrotreta sp.
Anomocare.

Fauna (near base):
Obolus, sp. undt.
Lingulella manticula (White) [1874, p. 9].
Billingsella coloradoensis (Shumard) [1860, p. 627].
Agnostus.
Ptychoparia.

ST. CHARLES FORMATION (continued):

	Feet
3 (continued):	
Fauna (a mixture of the faunas at the base and at the top):	
Obolus discoideus (Hall and Whitfield) [1877, p. 205].	
Obolus ? sp. undt.	
Lingulella manticula (White) [1874, p. 9].	
Billingsella coloradoensis (Shumard) [1860, p. 627].	
Huenella lesleyi Walcott [1908*d*, p. 110].	
Hyolithes.	
Cyrtolites.	
Agnostus.	
Ptychoparia.	
Anomocare.	
4. Bedded, light gray sandstone, followed below by dirty brown sandstone, and toward the base shaly and thin-bedded sandstone	166
Strike, north 20° east (magnetic); dip, 25° west.	
Fauna (in upper 20 feet):	
Obolus discoideus (Hall and Whitfield) [1877, p. 205].	
Obolus (*Fordinia*) *bellulus* (Walcott) [1905, p. 323].	
Acrotreta idahoensis alta Walcott [1902, p. 588].	
Billingsella coloradoensis (Shumard) [1860, p. 627].	
Fauna (near the base):	
Lingulella (*Lingulepis*) *acuminata* (Conrad) [1839, p. 64].	
Total Upper Cambrian	1,227

MIDDLE CAMBRIAN

NOUNAN FORMATION [Walcott, 1908*a*, p. 6]:

	Feet
1*a*. Light-gray, arenaceous limestone	12
1*b*. Lead-colored, arenaceous limestone	40
1*c*. Light-gray, arenaceous limestone	85
1*d*. Dark lead-gray, arenaceous limestone	87
1*e*. Shaly and thin-bedded arenaceous limestone with intercalated reddish brown sandy layers	15
1*f*. Light-gray, arenaceous limestone	18
1*g*. Dark lead-gray, arenaceous limestone	198
1*h*. Light-gray, arenaceous limestone	494
1*i*. Dark lead-gray, arenaceous limestone, with numerous irregular annelid borings filled with light-gray, arenaceous limestone	56
1*j*. Massive bedded, arenaceous, cherty limestone	8
1*k*. Bluish gray, cherty, more or less arenaceous limestone in thick bands that break up into thin layers on weathering	28
Total of 1	1,041

Fauna:

A few traces of fossils occur in the lower 28 feet and large annelid borings occur in many of the arenaceous limestones. If in a dark rock, the irregular borings are filled with lighter-colored rock, and in the light-gray rock by darker rock.

BLOOMINGTON FORMATION [Walcott, 1908*a*, p. 7]:

	Feet
1*a*. Thin-bedded, bluish gray, compact limestone with interbedded thick layers of gray limestone	22

Fauna:
Protospongia (spicules).
Obolus mcconnelli pelias (Walcott) [1905, p. 330].
Obolus (*Westonia*) *wasatchensis* Walcott [1908*d*, p. 69].
Lingulella desiderata (Walcott) [1898, p. 399].
Hyolithes.
Agnostus.
Ptychoparia.

1*b*. Greenish argillaceous shale	12
1*c*. Gray, coarse-grained limestone	13

Strike, north 20° east; dip, 20° west (magnetic).

Fauna:
Hyolithes.
Ptychoparia.

1*d*. Greenish argillaceous and sandy shale	147

Fauna (at base):
Hyolithes (fragments).
Agnostus.
Ptychoparia.

1*e*. Gray, coarse-grained limestone	4

Fauna:
Micromitra sculptilis (Meek) [1873, p. 479].
Hyolithes (abundant).
Ptychoparia.
Agraulos.

1*f*. Greenish argillaceous and sandy shale	22
Total of 1	220
2*a*. Bluish gray limestones, with small concretions and small nodules of calcite scattered through the layers, which range from an inch to 6 inches or more in thickness	380

Fauna:
Fragments of fossils.

2*b*. Massive bedded, gray limestone that forms a low cliff and breaks down readily on gentle slopes	132

Fauna:
Ptychoparia. } Same as in 1*e*.
Agraulos. }

2*c*. Bluish gray limestone, with small concretions and small nodules of calcite scattered through the layers; a limestone similar to 2*a*	290

BLOOMINGTON FORMATION (continued):

	Feet
2c (continued):	
Fauna:	
Hyolithes.	
Agraulos.	
2d. Greenish argillaceous shale	39
Fauna:	
Obolus (*Westonia*) *wasatchensis* Walcott [1908*d*, p. 69].	
Agraulos.	
Ptychoparia.	
At this horizon in Wasatch Canyon, 5 miles north of Brigham, *Acrothele subsidua* (White) [1874, p. 6] occurs.	
2e. Bluish gray, thin-bedded limestone	182
2f. Arenaceous, steel-gray limestone	22
2g. Bluish gray limestone, with small concretions and small nodules of calcite scattered irregularly through the layers	55
Fauna:	
Micromitra sculptilis (Meek) [1873, p. 479].	
Ptychoparia.	
Dorypyge.	
Total of 2	1,100
Total of Bloomington formation	1,320

BLACKSMITH FORMATION [Walcott, 1908*a*, p. 7]:

1a. Dark lead-gray, arenaceous limestone	195
1b. Arenaceous, steel gray, cliff-forming limestone, in the lower portion passing gradually into a dove-gray, compact limestone that weathers to a light-gray color. The layers vary in thickness from 4 inches to 2.5 feet	375
Fauna:	
Fragments of a small trilobite (*Ptychoparia ?*).	
Annelid borings.	
Total of Blacksmith formation	570

UTE FORMATION [Walcott, 1908*a*, p. 7]:

1a. Bluish gray, compact, thin-bedded limestone, with large irregular annelid borings in the upper part filled with steel-gray, arenaceous limestone similar to the beds above. Below the limestone is purer and more uniformly gray and in layers that tend to form low cliffs on the steeper slopes	290
Fauna (in upper part):	
Micromitra (*Paterina*) *labradorica utahensis* (Walcott) [1905, p. 306].	
Billingsella, sp. undt.	
Hyolithes.	
Agraulos.	

UTE FORMATION (continued):

	Feet
1*a* (continued):	
Ptychoparia subcoronata (Hall and Whitfield) [1877, p. 237].	
Dorypyge ? quadriceps (Hall and Whitfield) [1877, p. 240].	
130 feet below the top of 1*a* a large trilobite is indicated by a head and tail.	
1*b*. Gray, arenaceous limestone in thin layers, with occasional bands of layers 4 to 10 inches thick, often oölitic, and with interformational conglomerate and flattened concretions....	135
Fauna (in the upper 5 feet):	
Scenella.	
Ptychoparia subcoronata (Hall and Whitfield) [1877, p. 237].	
Dorypyge ? quadriceps (Hall and Whitfield) [1877, p. 240].	
Fauna (in layers 70 to 80 feet below the top):	
Micromitra (Paterina) labradorica utahensis (Walcott) [1905, p. 306].	
Obolus mcconnelli (Walcott) [1889, p. 441].	
Billingsella coloradoensis (Shumard) [1860, p. 627].	
Nisusia (Jamesella) nautes (Walcott) [1905, p. 283].	
Eoorthis zeno Walcott [1908*d*, p. 106].	
Syntrophia cambria Walcott [1908*d*, p. 106].	
Hyolithes.	
Scenella.	
Zacanthoides.	
Ptychoparia subcoronata (Hall and Whitfield) [1877, p. 237].	
Dorypyge ? quadriceps (Hall and Whitfield) [1877, p. 240].	
1*c*. Gray limestone, with numerous concretions one-fourth to one-half inches in diameter. A few thin layers of interformational conglomerate and some shaly limestone..............	58
Total of 1...	483
2*a*. Gray, fine-grained, calcareous and argillaceous shaly beds.....	38
Fauna:	
Micromitra (Paterina) labradorica utahensis (Walcott) [1905, p. 306].	
Obolus (Westonia) ella (Hall and Whitfield) [1877, p. 232].	
Acrothele cf. *turneri* Walcott [1908*d*, p. 87].	
Isoxys cf. *argentea* (Walcott) [1886, p. 146].	
Ptychoparia.	
2*b*. Bluish gray to blue-black, fine-grained, thin-bedded limestone.	57
Fauna:	
Obolus ?	
Ptychoparia.	

UTE FORMATION (continued):	Feet
2c. Greenish argillaceous and calcareous shale, weathering buff...	51
2d. Thin-bedded, grayish-blue limestone..........................	36
2e. Gray, oölitic limestone in layers 3 to 14 inches thick..........	24

Fauna:
Micromitra (*Paterina*) *stuarti* Walcott [1908*d*, p. 58].
Micromitra (*Paterina*) *superba* (Walcott) [1897, p. 711].
Hyolithes.
Ptychoparia a.
Ptychoparia b.
Dorypyge (fragment).

2f. Greenish argillaceous and sandy shale........................	18

Fauna:
Obolus mcconnelli (Walcott) [1889, p. 441].
Micromitra (*Paterina*) *superba* (Walcott) [1897, p. 711].
Ptychoparia, sp. undt.

2g. Bluish gray, thin-bedded limestone..........................	22

Strike, north 30° (magnetic); dip, 12° northwest.

Fauna (near base):
Micromitra (*Paterina*) *superba* (Walcott) [1897, p. 711].
Hyolithes.
Ptychoparia (small heads).

Total of 2..	246

Spence shale [Walcott, 1908*a*, p. 8]:

1. Greenish argillaceous and sandy shale.......................	30

Fauna:
Micromitra (*Iphidella*) *pannula* (White) [1874, p. 6].
Obolus (*Westonia*) *ella* (Hall and Whitfield) [1877, p. 232].
Hyolithes.
Orthotheca major Walcott [1908*c*, p. 246, pl. I, fig. 11].
Leperditia.
Ptychoparia.
Bathyuriscus productus (Hall and Whitfield) [1877, p. 244].

At Wasatch Canyon, 5 miles north of Brigham, Utah, the following were found at this horizon:

Eocystites ? longidactylus Walcott [1886, p. 94].
Micromitra (*Iphidella*) *pannula* (White) [1874, p. 6].
Obolus (*Westonia*) *ella* (Hall and Whitfield) [1877, p. 232].
Lingulella desiderata (Walcott) [1898, p. 399].
Acrothele subsidua (White) [1874, p. 6].
Agnostus.
Ptychoparia piochensis Walcott [1886, p. 201].
Zacanthoides idahoensis Walcott [1908*b*, p. 26].

Spence shale (continued):

1 (continued):

Neolenus a.
Neolenus b.
Bathyuriscus howelli Walcott [1886, p. 216].
Bathyuriscus productus (Hall and Whitfield) [1877, p. 244].
Ogygopsis.

LANGSTON FORMATION [Walcott, 1908*a*, p. 8]:

Feet

1*a*. Massive bedded, bluish gray limestone, passing downward into gray, arenaceous limestone with many round concretions, one-fourth to three-fourths of an inch in diameter.......... 64

Fauna:
Obolus (Westonia) ella (Hall and Whitfield) [1877, p. 232].
Zacanthoides sp.
Bathyuriscus productus (Hall and Whitfield) [1877, p. 244]?
Neolenus ?

1*b*. Massive bedded, bluish gray limestone that breaks up into layers 2 to 8 inches thick on weathering and with many round concretions 44

Fauna:
Ptychoparia.
Bathyuriscus productus (Hall and Whitfield) [1877, p. 244].

In the section two miles southeast of Malade, Idaho, a section which is 60 miles northwest of Blacksmith Fork, the fauna at this horizon is large and finely preserved in compact, bluish gray limestones. It includes:

Micromitra haydeni Walcott [1908*d*, p. 55].
Micromitra (Iphidella) pannula (White) [1874, p. 6].
Micromitra (Iphidella) pannula ophirensis (Walcott) [1905, p. 306].
Lingulella desiderata (Walcott) [1898, p. 399].
Lingulella helena (Walcott) [1898, p. 406].
Lingulella isse (Walcott) [1905, p. 330].
Acrotreta idahoensis sulcata Walcott [1902, p. 588].
Acrotreta pyxidicula White [1874, p. 9].
Acrotreta ?
Acrothele artemis Walcott [1908*d*, p. 82].
Acrothele subsidua (White) [1874, p. 6].
Acrothele subsidua, var.
Acrothyra minor Walcott [1905, p. 303].
Billingsella coloradoensis (Shumard) [1860, p. 627].
Hyolithes.

LANGSTON FORMATION (continued):	Feet
Orthotheca.	
Stenotheca.	
Platyceras.	
Agnostus.	
Microdiscus.	
Solenopleura.	
Ptychoparia (2 species).	
Oryctocephalus.	
Dorypyge (2 species).	
Neolenus (2 species).	
Asaphiscus.	
Ogygopsis?	
2. Massive bedded, dark, arenaceous limestone, passing at about 150 feet down into a calcareous sandstone, and then a gray sandstone	390
Total of Langston formation	498
BRIGHAM FORMATION [Walcott, 1908*a*, p. 8]:	
1*a*. Quartzitic sandstone, gray, greenish, gray brownish, dirty gray, all weathering reddish dirty brown in layers 3 inches to 3 feet in thickness	28
1*b*. Greenish, hard, sandy shale	4
Fauna:	
Annelid trails.	
Trilobite tracks.	
1*c*. Same as 1*a* (estimated)	1,200+
Total of Brigham formation	1,232
Total of Middle Cambrian[1]	5,420+

RÉSUMÉ, BLACKSMITH FORK SECTION

UPPER CAMBRIAN:		
ST. CHARLES FORMATION:	Feet	Feet
1. Fossiliferous limestone	190	
2. Arenaceous limestone	777	
3. Fossiliferous limestone	94	
4. Shaly and thin-bedded sandstones	166	
		1,227
MIDDLE CAMBRIAN:		
NOUNAN FORMATION:		
1. Arenaceous limestone		1,041
BLOOMINGTON FORMATION:		
1. Limestone and shales	220	
2. Thin-bedded limestone	1,100	
		1,320

[1] The line of separation between the Middle and Lower Cambrian occurs somewhere in the Brigham formation, and this thickness (5,420 feet) likely includes several hundred feet of Lower Cambrian beds.

RÉSUMÉ, BLACKSMITH FORK SECTION (continued):

		Feet
BLACKSMITH FORMATION:		
1. Arenaceous limestone		570
UTE FORMATION:		
1. Thin-bedded limestone	483	
2. Limestone and shales	246	
	——	729
Spence shale		30
LANGSTON FORMATION:		
1. Massive limestone	108	
2. Arenaceous limestone	390	
	——	498
BRIGHAM FORMATION:		
1. Quartzitic sandstones (estimated)		1,232+
Total Middle Cambrian[1]		5,420+
Total section		6,647+

DEARBORN RIVER SECTION

Locality.—North fork of the Dearborn River, south-southeast and south of Mount Dearborn, Lewis and Clark Forest Reserve, Montana.

The base of the section is 4 miles above Walker's ranch at the mouth of the canyon. The summit is the top of Mount Dearborn.

CARBONIFEROUS

	Feet
1. Brown, thin-bedded sandstone	135
2*a*. Massive bedded, light gray, siliceous limestone, forming a high cliff and breaking into talus slopes of small angular fragments	1,970
Fossils: Noted *Zaphrentis* and *Syringopora* in abundance.	
2*b*. Massive bedded dark gray, siliceous limestone breaking into fragments; 275 feet from the top there is a thin bed of shaly limestone	425
2*c*. Thin-bedded, steel-gray, buff, and gray weathering limestone	725
Very few fossils were observed. A large *Spirifer* and specimens of a large *Productus* were noted about 400 feet from the top.	
Total Carboniferous	3,255

SILURIAN (?)

The strata referred to the Silurian are arenaceous limestones in which no fossils were observed. It is not improbable that the upper portion of them may be of Devonian age, or possibly Lower Carboniferous.

[1] See footnote on page 199.

	Feet
3*a*. Massive bedded, gray, arenaceous cliff-forming limestones.....	675
3*b*. Thin-bedded, gray limestone and sandstone, with small lentiles of light-gray limestone. The irregular arenaceous portions weather buff and form a buff band where the rock is in the cliffs	75
3*c*. Massive bedded, light gray, arenaceous limestone, with thinner bedded, purer limestones at intervals. On the mountain slopes the massive beds form cliffs, and the thin-bedded more shaly portion forms slopes........	245
3*d*. Massive bedded, light gray, arenaceous limestone, with somewhat purer, slightly banded limestones toward the top......	175
3*e*. Massive bedded light gray, banded limestones, that break up into thin and often shaly layers on exposure to the weather.	51
3*f*. Massive bedded, light gray, arenaceous limestones...........	164
Total of Silurian ?........	1,385

The line drawn between the Cambrian and the Silurian is based largely on the change in the character of the limestone, from the coarse, gray, arenaceous limestone to a much purer, gray limestone, and the occurrence, about 150 feet from the top, of fragments of a species of *Ptychoparia*.

CAMBRIAN

LIMESTONE:

	Feet
1*a*. Massive bedded, hard, gray and bluish gray limestones that break up into thin, irregular layers on exposure to the weather. The color of many thin layers and the thick layers on their bedding planes is yellow to buff. The upper 100 feet contain massive dove-colored limestones and near the top a few feet of siliceous limestone........	550
Fragments of a species of *Ptychoparia* were noted about 150 feet below the summit.	
1*b*. Greenish and gray, thin-bedded limestone, with some arenaceous shale and thin layers of greenish sandstone in the shale	90
Numerous annelid trails and fragments of trilobites occur throughout.	
1*c*. Massive bedded, gray limestone that breaks up into thin, irregular layers, in very much the same manner as the Pilgrim limestone, but is usually more massive. It is quite arenaceous near the central portions, where it is more massive bedded for a short distance........	680
One hundred and seventy feet from the top there is a band of thin-bedded oölitic limestone, in which fragments of trilobites are numerous; also a small *Obolus*-like shell. Oölitic limestone, interbedded with irregular, thin-bedded, bluish gray limestones, occurs in the lower 170 feet.	
Total of limestone........	1,320

		Feet
SHALE:		
2.	Thin-bedded limestones, with partings of greenish, argillaceous, and arenaceous shale. Sometimes the shale and at other times the limestone predominates	150
LIMESTONE:		
3.	Massive bedded, gray limestone, similar to the Meagher limestone, except that it is of a lighter gray color near the top..	130
	Annelid trails are abundant and fragments of tribolites.	
SHALE:		
4.	Thin-bedded limestones, with partings of greenish, argillaceous, and arenaceous shale, the limestones predominating. It breaks down readily on the slopes and forms a sloping terrace	210
LIMESTONE:		
5.	Massive bedded, fine-grained, gray limestone that breaks up on weathering into thin layers from a quarter of an inch to two inches in thickness. They have a very irregular surface, marked by a thin, buff-colored deposit that fills the annelid burrows and trails, and also occurs as irregular blotches on the surface.	
	This belt of limestone is divided into five thick beds that may be distinguished for miles in the cliffs. The two lower are usually broken down	55
	Annelid trails are abundant and numerous fragments of trilobites.	
SHALE:		
6.	Greenish purple and dark gray, argillaceous shales, with thin layers of sandstone and arenaceous shale at irregular intervals	190

Shale No. 6 is in the same stratigraphic position as the Wolsey shale [Weed, 1900, p. 285] of the Little Belt Mountains section, and the sandstone beneath corresponds stratigraphically to the Flathead sandstone [Peale, 1893, p. 20] in the same section. The fauna of shale No. 6 on Scapegoat and Gordon mountains, localities west of the Dearborn River section, is, however, entirely unlike that of the Middle Cambrian Wolsey shale, and includes the following species:

Micromitra (*Iphidella*) *pannula* (White) [1874, p. 6].
***Obolus* (*Westonia*) *ella* (Hall and Whitfield) [1877, p. 232].**
Acrothele colleni, new species.
Acrothele panderi, new species.
Wimanella simplex Walcott [1908*d,* p. 101].
Olenopsis ? sp.
Ptychoparia, sp.
Albertella helena Walcott [1908*b,* p. 19].

Vanuxemella contracta, new genus and new species.
Bathyuriscus productus ? (Hall and Whitfield) [1877, p. 244].
Bathyuriscus ?.

This fauna is strikingly similar to that occurring in the drift blocks which are believed to have come from the lower portion of the Mount Whyte formation of the Mount Bosworth section [see page 214]. At the localities in question neither fauna contains *Olenellus,* but that genus occurs so generally in the Mount Whyte formation, both above and below the Albertella horizon, that the entire formation is placed in the Lower Cambrian. This correlation places shale No. 6 and sandstone No. 7 in the Lower Cambrian.

SANDSTONE:

	Feet
7a. Thin-bedded sandstones, with partings of dark arenaceous shale Many varieties of annelid trails and tracks of trilobites occur on the surface of the sandstone.	70
7b. Massive bedded, coarse, more or less cross-bedded, light gray sandstone, with a few thin layers of fine quartzitic conglomerate	80
Total of sandstone	150

RÉSUMÉ, DEARBORN RIVER SECTION

	Feet
1. Limestone	1,320
2. Shale	150
3. Limestone	130
4. Shale	210
5. Limestone	55
6. Shale	190
7. Sandstone	150
Total of Cambrian	2,205

Beneath the Cambrian sandstone the Empire shales of the Belt Terrane of the Algonkian occur with apparently the same strike and dip as the base of the sandstone. Traced on the strike, however, they appear to be unconformably beneath the sandstone.

MOUNT BOSWORTH SECTION

Mount Bosworth section, north of Hector, British Columbia, on the Continental Divide, north of the Canadian Pacific Railway.

The summit of the section is on the west spur (Sherbrooke ridge) of Mount Bosworth overlooking Sherbrooke Lake. The highest beds are on the south summit of the ridge, and from their lithologic character and the finding of obscure fossils that suggest *Ophileta* of the Lower Ordovician the upper 110 feet of strata are tentatively referred to the Ordovician system. The strata near the summit are much broken up owing to a fault line that crosses the ridge.

ORDOVICIAN

Feet

1. Massive bedded gray and bluish gray arenaceous limestone, with thin layers, irregular stringers, and nodules of dark chert 110

UPPER CAMBRIAN

SHERBROOKE FORMATION [Walcott, 1908*a*, p. 2]:

1. Massive bedded, bluish gray limestone, with some cherty matter in the form of small nodules and stringers; also irregular partings and fillings of annelid borings by gray dolomitic limestone weathering buff 175

   Fauna:
   Annelid borings and trails.
   Fragments of undeterminable trilobites.

2*a*. Gray oölitic limestone in thick layers, with bluish banded limestone intercalated at irregular intervals. The banded appearance of the nonoölitic layers is owing to the buff weathering of the thin dolomitic layers 190

   Fauna (Upper Cambrian facies):
   Crepicephalus.
   Pterocephalus ?
   Ptychoparia.

2*b*. Greenish drab and gray siliceous shales with interbedded oölitic limestone in bands of layers from 6 inches to 4 feet thick; also a few bands of thick-bedded, bluish gray limestone that breaks up into shaly limestone on weathering 335

   Fauna (in green shales near summit):
   Lingulella isse (Walcott) [1905, p. 330].

   Fauna (in oölitic layers):
   Agnostus, sp. undt.
   Illænurus.
   Ptychoparia.

SHERBROOKE FORMATION (continued):

	Feet
2c. Gray oölitic limestone, with thin bands of interbedded shaly, blue gray limestone. Gray, dolomitic, buff-weathering, flattened nodules, stringers, and thin layers of limestone occur in a very irregular manner	65

Fauna:
Illænurus.
Agnostus.
Ptychoparia.
Bathyurus-like pygidia.

Total of 2	590
3. Arenaceous, dolomitic, steel gray limestone weathering light gray and buff gray	610

The line of demarcation between 3 and the bluish gray limestones below is irregular. The gray beds of 3 extend along the cliff and abruptly change to bluish gray. In the upper 100 feet of 3 irregular masses of bluish gray limestone occur like great lentiles, as though they were cores left in the general alteration (dolomitization) of the strata.

Total of Sherbrooke formation	1,375

PAGET FORMATION [Walcott, 1908*a*, p.3]:

1. Massive bedded, dark bluish gray limestone forming base of cliff on the west side of the amphitheater on the west slope of Mount Bosworth and, with 3 of Sherbrooke formation, the upper cliffs of Paget Peak and Mount Daly	60
2. Massive beds of oölitic limestone, with irregular, interbedded bands of green siliceous shale. Thin layers, irregular stringers, and nodules of gray buff weathering dolomite occur in the oölitic limestones	300+

The base of 2 is covered by talus slope on line of the section. It is well exposed on the southeast face of Mount Daly and Paget Peak. The thickness is placed at 300 feet, which I think is less than the total thickness. Over 200 feet was measured.

Fauna:
Hyolithes.
Agnostus.
Crepicephalus.

Total of Paget formation	360+

BOSWORTH FORMATION [Walcott, 1908*a*, p.3]:

1. Massive bedded, gray, and bluish gray arenaceous dolomitic limestone. Several bands of steel gray, yellowish buff weathering bands of strata occur in the lower half of 1	600+

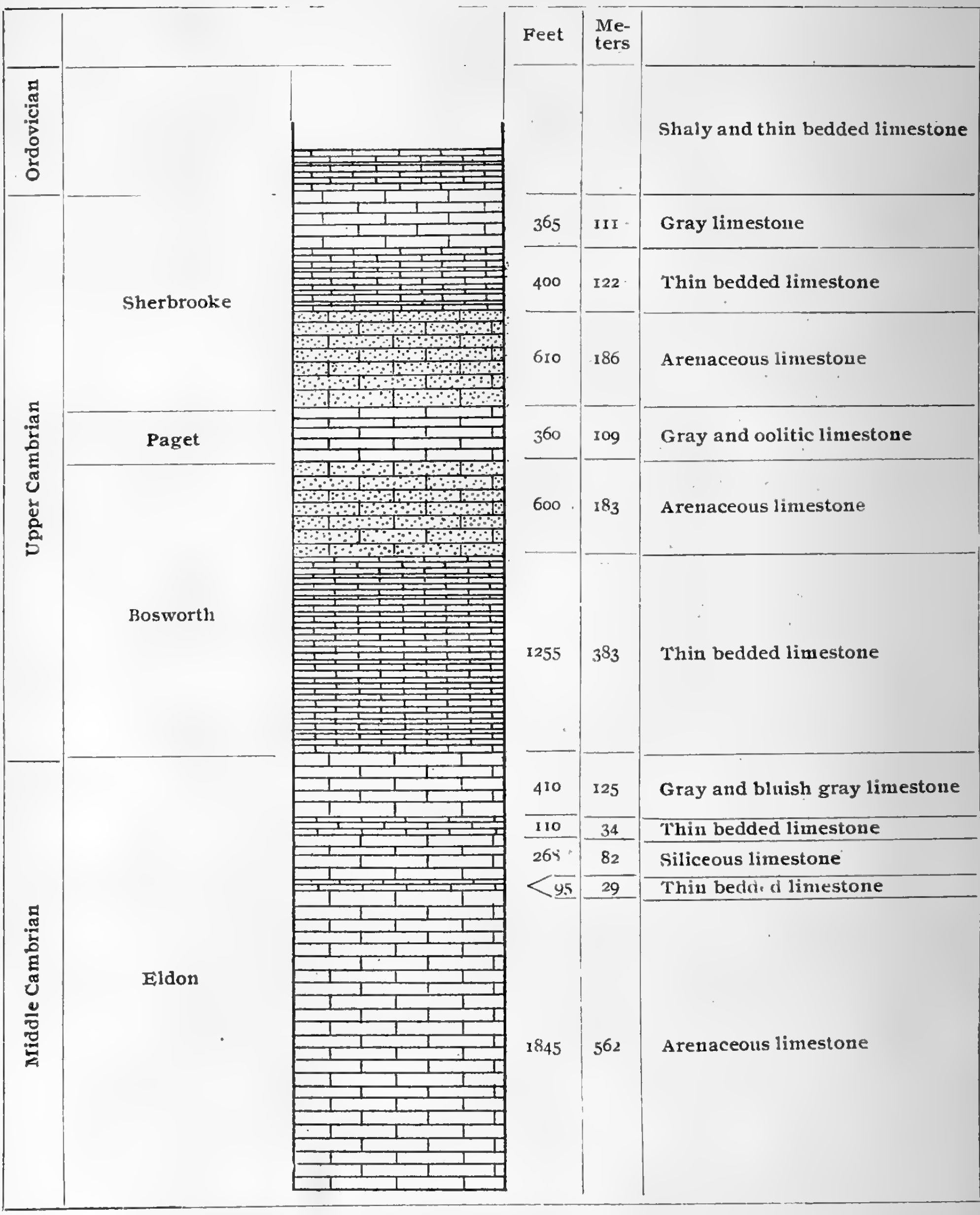
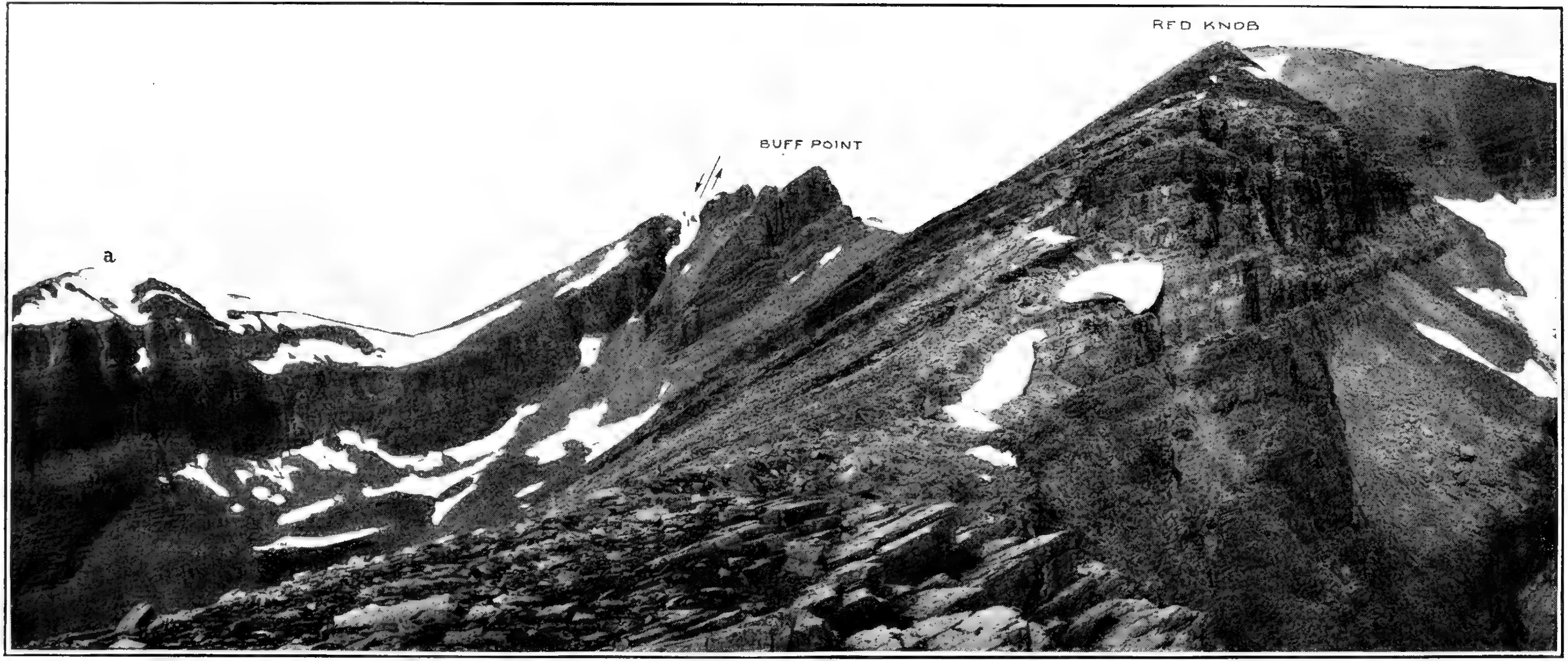


Fig. 8.—Mt. Bosworth Section (continued on following page)



EASTERN SIDE OF SHERBROOKE RIDGE

The summit of the ridge at (*a*) is formed of strata tentatively referred to the Ordovician. Below, the Sherbrooke and Paget formations extend down to the foot of the cliffs. Buff Point and Red Knob expose the Bosworth formation nearly down to the great Eldon siliceous limestone. A fault brings the base of the Paget formation up about 500 feet.

			Feet	Meters	
Middle Cambrian		Section continued from preceding page			
	Stephen		150	46	Ogygopsis shale (lentile)
			315	96	Shaly limestone
			325	99	Alternating shales and limestone
	Cathedral		1595	486	Arenaceous limestone
Lower Cambrian	Mt. Whyte		224	68	Thin bedded limestone
			31	9	Sandstone
			115	35	Shale
			20	6	Limestone
	St. Piran		2705	824	Quartzitic sandstone
	Lake Louise >		< 105	32	Siliceous shale
	Fairview		600	183	Quartzitic sandstone

FIG. 9.—Mt. Bosworth Section (continued)

NOTE.—The thickness of the St. Piran, Lake Louise, and Fairview formations is taken from the Lake Louise section.

BOSWORTH FORMATION (continued):

1 (continued): Feet

This formation forms the base of the high cliffs on the southeast face of Mount Daly and Paget Peak.

The lower portion of 1 was measured and the upper parts estimated. The thickness given is probably 100 feet oi more less than the actual thickness.

2a. Shaly and thin-bedded, gray and dove-colored, compact fine-grained dolomitic limestone weathering buff and light gray. Thicker layers occur in bands from 1 to 6 feet thick........ 422

2b. Greenish siliceous shale with thin interbedded layers of siliceous, compact, gray limestone........................... 48

Fauna:

At about this horizon in the Castle Mountain section 20 miles southeast of Mount Bosworth small trilobite heads of the genera *Ptychoparia* and *Solenopleura* occur in a band of gray and bluish black limestone, and just below fragments of a species of *Obolus.*

2c. Limestones similar to *2a*.................................. 517

Total of 2.. 987

3. Variable arenaceous shales with alternating bands of color—greenish, deep red, buff, yellow, and gray.

Numerous mud cracks and ripple-marks occur on many of the layers 268

Total of Bosworth formation...................... 1,855
Total Upper Cambrian............................. 3,590

NOTE.—The 1,855 feet of strata included in 1, 2, and 3 remind me, in lithologic character and appearance, of strata of the upper portions of the Cambrian Belt Terrane of Montana. No traces of life were observed and the shaly, banded character of the beds is very striking.

MIDDLE CAMBRIAN

ELDON FORMATION [Walcott, 1908*a*, p.3]:

1a. Irregularly bedded, gray, siliceous and arenaceous limestone in thick layers above and thin layers below; at 192 feet from the base a bed of bluish black limestone is fossiliferous. Above the fossiliferous bed the strata become more massive, arenaceous, steel gray in color, weathering to a light gray... 410

Fauna (192 feet above the base):

Agnostus, sp.
Ptychoparia, 2 species.
Bathyuriscus-like pygidium.

1b. Light and dark gray, thin-bedded, arenaceous limestone, weathering to a light-gray color................................ 110

1c. Massive bedded, siliceous, fine-grained, compact, dark bluish gray limestone.. 197

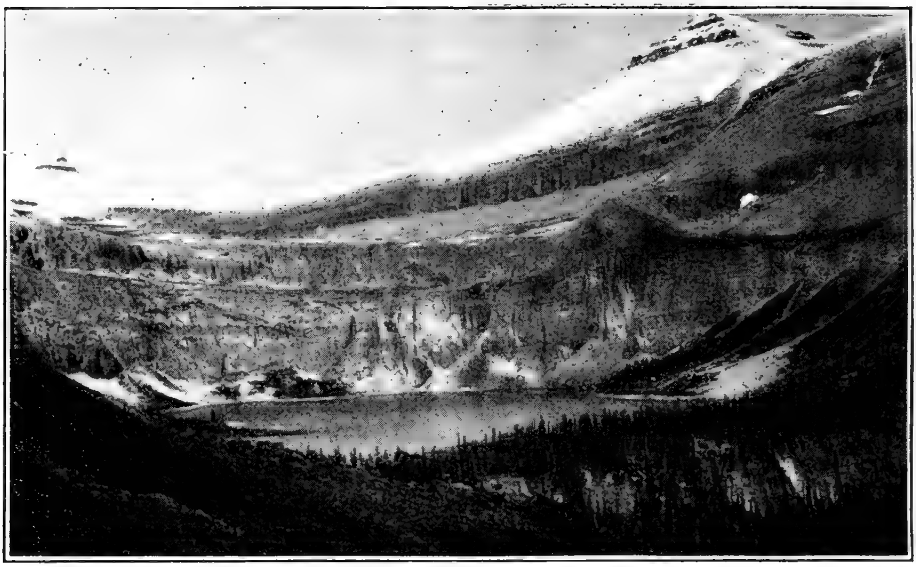


Fig. 1. NORTH RIDGE OF CASTLE MOUNTAIN

Showing the Eldon formation in the cliffs above the lake and the Bosworth formation in the snow-covered points above the cliff line.

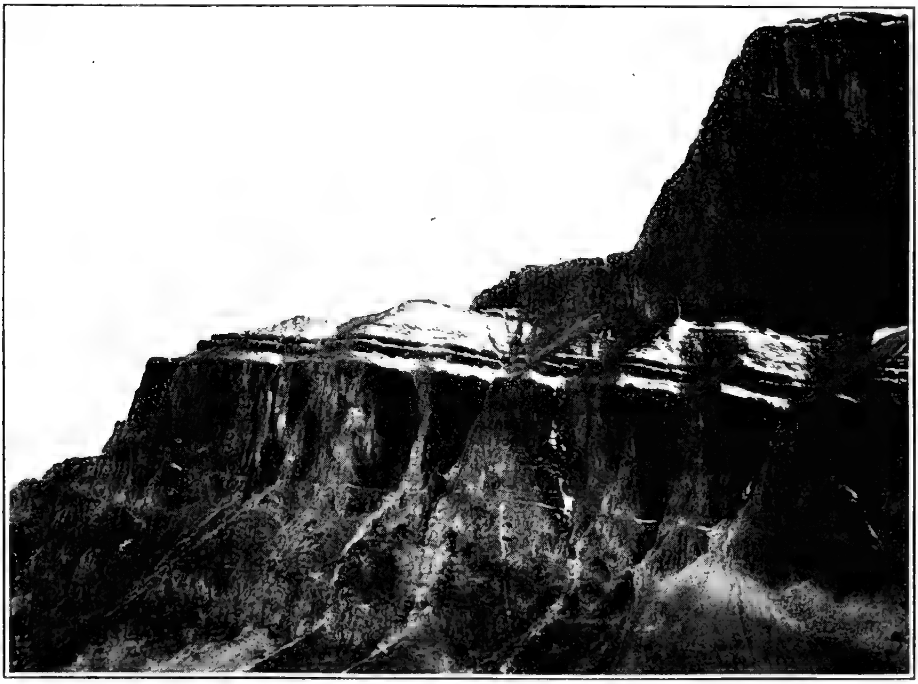


Fig. 2. PROFILE OF SOUTHEAST FRONT OF CASTLE MOUNTAIN, OPPOSITE ELDON

The upper cliff is formed of the siliceous limestone of the Eldon formation; the terrace with snow on it the Stephen formation, and the lower cliff and slope the Cathedral formation. These formations are finely exposed on Mount Bosworth, but not so as to get good photographs of them.

ELDON FORMATION (continued):

1*c* (continued): Feet

Two yellowish buff weathering bands of limestone 2 to 3 feet thick stand out in color on the face of cliffs.

Fauna (near the summit):
Billingsella ?
Neolenus-like pygidium.

1*d*. Massive bedded limestone much like that of 1*c*.............. 71

Total of 1.. 788

2. Thin-bedded, bluish gray limestone with irregular layers and stringers of gray, buff weathering, dolomitic limestone........ 95
At 24 feet from the base a shaly, bluish gray, siliceous limestone about two feet thick is interbedded.

Fauna (in shaly limestone):
Obolus membranaceous Walcott [1908*d*, p. 61].
Lingulella sp.
Isoxys argentea (Walcott) [1886, p. 146].
Ptychoparia, 2 species.

3. Massive bedded dark gray arenaceous limestone.............. 190
4. Massive bedded, cliff-forming, light gray arenaceous limestone. At several horizons bands of thinner layers from a few feet up to 30 feet in thickness occur. One of these 480 feet from the base forms a slight terrace.................. 1,655

Fauna:

In the Mount Stephen section seven miles southwest of Mount Bosworth, at a horizon about 700 feet above the base of this limestone, the following fossils have been recognized:
Protospongia (spicules).
Lingulella cf. *isse* (Walcott) [1905, p. 330].
Hyolithes sp.
Agnostus cf. *montis* Matthew [1899, p. 43].
Zacanthoides spinosus Walcott [1884, p. 63].
Ptychoparia sp.
Bathyuriscus sp.
Ogygopsis sp.

Total of Eldon formation........................ 2,728

STEPHEN FORMATION [Walcott, 1908*a*, p.3]:

1. Thin-bedded, dark gray and bluish black limestone........... 315

Fauna:
Micromitra (*Paterina*) *stissingensis* (Dwight) [1889, p. 145].
Obolus mcconnelli (Walcott) [1889, p. 441].

STEPHEN FORMATION (continued):

1 (continued):

Nisusia alberta (Walcott) [1889, p. 442], var.
Hyolithes carinatus Matthew [1899, p. 42].
Agnostus sp.
Agraulos sp.
Menocephalus sp.
Ptychoparia, 3 species.
Neolenus sp.
Bathyuriscus sp.

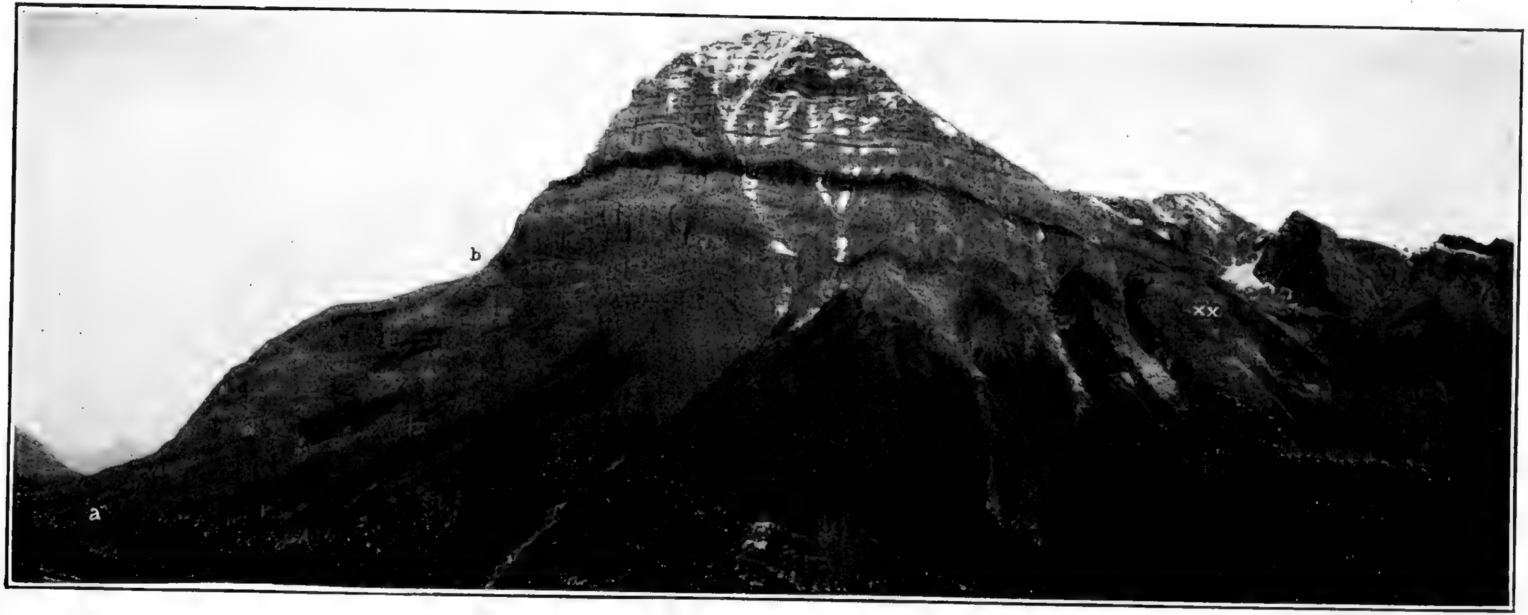
At Mount Stephen, about seven miles southwest of Mount Bosworth, a siliceous shale occurs at the summit of the Stephen formation in which an unusually rich fauna occurs. This shale is not well developed on Mount Bosworth.

OGYGOPSIS SHALE.—This term is applied to the local development of arenaceous and calcareous shale at the summit of the Stephen formation on the northwest slope of Mount Stephen. The shale band (lentile) has a maximum thickness of about 150 feet. It thins out to the northeast and is faulted out to the southwest. At its maximum thickness, 2,800 feet above Field, it carries immense numbers of trilobites, especially *Ogygopsis klotzi* (Rominger), *Bathyuriscus rotundatus* (Rominger), *Neolenus serratus* (Rominger), *Zacanthoides spinosus* (Walcott), and, in addition, sponges, cystids, brachiopods, pteropods, and gasteropods. The shale is less rich in fossils one-fourth of a mile northeast on the strike; also to the northwest. Lentiles of gray quartzitic sandstone and siliceous, gray limestone occur in the shale, and the entire shale band appears to be a lentile between the thin-bedded blue limestones and the superjacent massive, arenaceous limestone formation. There is no trace of the *Ogygopsis* shale on Mount Bosworth 6 miles northeast, at the same horizon, or at Castle Mountain, 20 miles east-southeast.

There is a sharp anticline, with a northeast-southwest axis, in the shale and the thin-bedded limestones beneath, on the northwest slope of Mount Stephen. The southeast limb is crushed and the beds are largely faulted out against the massive arenaceous limestone before reaching the amphitheater at the head of Field Brook. On the northwest limb the shales are unaltered and slope down the side of the mountain for 1,800 feet, thus affording a great exposure of the shale and contained fossils.

Fauna:

1. *Hyolithellus flagellum* (Matthew) [1899, p. 40].
2. *Hyolithellus annulatus* (Matthew) [1899, p. 42].
3. *Orthotheca corrugata* Matthew [1899, p. 42].
4. *Orthotheca major* Walcott [1908*c*, p. 246, pl. I, fig. 11].
5. *Hyolithes,* sp.
6. *Hyolithes carinatus* Matthew [1899, p. 42].
7. *Stenotheca wheeleri* Walcott [1908*c*, p. 245, pl I, fig. 7].
8. *Platyceras romingeri* Walcott [1889, p. 442].
9. *Platyceras bellianus* Walcott [1908*c*, p. 246, pl. I, fig. 13].
10. *Acrotreta depressa* (Walcott) [1889, p. 441].
11. *Micromitra (Iphidella) pannula* (White) [1874, p. 6].
12. *Obolus mcconnelli* (Walcott) [1889, p. 441].
13. *Nisusia alberta* Walcott [1889, p. 442].
14. *Philhedra columbiana* (Walcott) [1889, p. 441].



MOUNT STEPHEN, BRITISH COLUMBIA, FROM THE NORTH

Near the base at (*a*) the Mount Whyte formation rests on the St. Piran quartzitic sandstones. The great Cathedral arenaceous limestone forms the north shoulder of the mountain up to (*b*), where the 800 feet of the Stephen formation breaks the profile. Above this the massive beds of the Eldon formation extend to the summit of the peak. The section shown in the profile is over 5,800 feet in thickness. At *xx* on the slope the great fossil beds of the Stephen formation are finely exposed.

STEPHEN FORMATION (continued):

Ogygopsis shale (continued): Feet

15. *Scenella varians* Walcott [1886, p. 127].
16. *Anomalocaris canadensis* Whiteaves [1892, p. 207].
17. *Anomalocaris ? whiteavesi* Walcott [1908*c*, p. 246, pl. II, figs. 2, 2*a*, 4, 6, and 6*a*[.
18. *Anomalocaris ?? acutangula* Walcott [1908*c*, p. 247, pl. II, fig. 5].
19. *Agnostus montis* Matthew [1899, p. 43].
20. *Dorypyge (Kootenia) dawsoni* (Walcott) [1889, p. 446].
21. *Bathyuriscus rotundatus* (Rominger) [1887, p. 16].
22. *Bathyuriscus pupa* Matthew [1899, p. 51] probably = 23.
23. *Bathyuriscus occidentalis* (Matthew) [1899, p. 49].
24. *Bathyuriscus ornatus* Walcott [1908*b*, p. 39].
25. *Karlia stephenensis* Walcott [1889, p. 445].
    Corynexochus romingeri Matthew [1899, p. 47] = 25.
26. *Neolenus serratus* (Rominger) [1887, p. 13].
    Neolenus granulatus Matthew [1899, p. 55]=26.
27. *Ogygopsis klotzi* (Rominger) [1887, p. 12].
28. *Oryctocephalus reynoldsi* Reed [1899, p. 359].
    Oryctocephalus walkeri Matthew [1899] = 28.
29. *Burlingia hectori* Walcott [1908*b*, p. 15].
30. *Ptychoparia cordilleræ* (Rominger) [1887, p. 17].
    Conocephalites cf. *perseus* Hall, Matthew [1899, p. 46] = 30.
31. *Ptychoparia palliseri* Walcott [1908*c*, p. 247, pl. III, fig. 6].
32. *Zacanthoides spinosus* (Walcott) [1884, p. 63].

2*a*. Greenish siliceous shale 23

Fauna:

Obolus (Westonia) ella ? (Hall and Whitfield) [1877, p. 232].

2*b*. Thick-bedded, bluish gray limestone, breaking up into thin layers one-half to 3 inches thick on weathering............ 22

Fauna:

Micromitra (Paterina) stissingensis (Dwight) [1889, p. 145].

Nisusia alberta Walcott [1889, p. 442], var.

2*c*. Greenish siliceous shale.................................... 70

2*d*. Alternating bluish gray, bedded, compact limestone, siliceous and arenaceous shale, mostly shale below.................. 210

Total 2.. 325

Fauna:

Cruziana.

Micromitra (Iphidella) pannula (White) [1874, p. 6].

Obolus (Westonia) ella (Hall and Whitfield) [1877, p. 232].

Hyolithes.

Leperditia.

Ptychoparia.

Bathyuriscus.

STEPHEN FORMATION (continued):

2d (continued): Feet

On Mount Stephen, at a horizon 150 feet from the base of this limestone, the fauna includes:

Micromitra (*Iphidella*) *pannula* (White) [1874, p. 6].
Billingsella marion Walcott [1908*d*, p. 102].
Hyolithes.
Microdiscus.
Ptychoparia.

CATHEDRAL FORMATION [Walcott, 1908*a*, p. 4]:

1*a*.	Thin-bedded gray to lead-gray, arenaceous limestones, weathering buff gray to dull light gray	404
1*b*.	Massive bedded, steel-gray weathering, light gray, arenaceous limestone. In some localities thinner layers appear at various horizons and large lentiles of dark lead-gray-colored beds occur very irregularly	682
1*c*.	Similar to 1*a*. Annelid borings and trails occur in and on some of the layers	126
1*d*.	Similar to 1*b*	83
1*e*.	Thin-bedded, lead-gray to blue-gray, thin-bedded (layers 1 inch to 4 inches thick) arenaceous limestone	25
1*f*.	Alternating thin and massive bedded, arenaceous, steel-gray limestone weathering light gray	275
	Total of 1	1,595

LOWER CAMBRIAN

MOUNT WHYTE FORMATION [Walcott, 1908*a*, p. 4]:

The line between the Middle and Lower Cambrian is placed at this horizon on account of the presence in the Mount Stephen section of *Olenellus* in the limestone 116 feet below the massive arenaceous limestone belt represented by 1*f* in the Cathedral formation of the Mount Bosworth section.

1*a*. Thin-bedded, bluish gray, slightly arenaceous limestone........ 120

Fauna:
Numerous annelid trails and borings.

1*b*. Gray oölitic limestone in layers 3 to 6 inches thick............ 44

Fauna (4 feet from base):
Nisusia (*Jamesella*) *lowi* Walcott [1908*d*, p. 98].
Microdiscus, sp. undt.
Agraulos sp.
Ptychoparia sp.

At Castle Mountain fragments of a species of *Bornemannia* (new genus allied to *Zacanthoides*) occur at about this horizon.

MOUNT WHYTE FORMATION (continued):

1*b* (continued): Feet

In the Mount Stephen section the following species occur at a horizon near the top of this limestone:

Nisusia (*Jamesella*) *lowi* Walcott [1908*d*, p. 98].
Stenotheca elongata Walcott [1884, p. 23], var.
Scenella varians Walcott [1886, p. 127].
Platyceras, new species.
Hyolithes billingsi Walcott [1886, p. 134].
Ptychoparia sp.
Crepicephalus, new species.
Protypus, new species.
Albertella, sp. undt.

About 50 feet down in the Mount Stephen section in a gray, siliceous shale the following species occur:

Cystid plates.
Micromitra (*Paterina*), sp. undt.
Acrotreta sagittalis taconica (Walcott) [1887, p. 189].
Nisusia (*Jamesella*) *lowi* Walcott [1908*d*, p. 98].
Hyolithes (fragment).
Hyolithellus cf. *micans* Billings [1872, p. 215].
Scenella varians Walcott [1886, p. 127].
Olenellus (fragments of thoracic segments).

1*c*. Massive layers made up of banded bluish gray limestone and sandstone in layers one-half inch to 2 inches thick.......... 60

Fauna:
Agraulos, sp. undt.

Total of 1.. 224

On Mount Stephen, at a horizon near the top of this bed of limestone, there was found:
Acrothele colleni, new species.
Acrotreta sagittalis taconica (Walcott) [1887, p. 189].
Scenella varians Walcott [1886, p. 127].
Stenotheca elongata Walcott [1884, p. 23], var.
Albertella, sp. undt.
Olenellus (fragments).
Bathyuriscus, sp. undt.

Near the base on Mount Stephen:
Micromitra (*Paterina*) *labradorica* (Billings) [1861, p. 6], var.
Micromitra (*Iphidella*) *pannula* (White) [1874, p. 6].
Acrotreta sagittalis taconica (Walcott) [1887, p. 189].
Bornemannia prima, new genus and new species.
Ptychoparia, 3 species.

2. Gray and brownish gray sandstone in thin and massive layers. 31

MOUNT WHYTE FORMATION (continued):

2 (continued): Feet

Fauna:
Hyolithes.
Agraulos.

On Mount Stephen, at this horizon, there were found:
Microdiscus, sp. undt.
Olenellus, sp. undt. (fragments).
Ptychoparia, sp. undt.
Protypus, sp. undt.

3. Siliceous shale with a few interbedded thin layers of compact, hard, gray sandstone.................................... 115

In the Lake Agnes section 5 miles southeast of Mount Bosworth, the fauna of about this horizon includes:
Micromitra (*Paterina*) *wapta* Walcott [1908*d*, p. 59].
Obolus parvus Walcott [1908*d*, p. 61].
Hyolithes billingsi Walcott [1886, p. 134].
Olenopsis agnes, new species.
Ptychoparia, 3 species.
Albertella, sp. undt.
Bathyuriscus.

On the south slope of Mount Bosworth two drift blocks of siliceous shale, supposed to be from this horizon, were found, from which the following species were collected:
Micromitra (*Paterina*) *wapta* Walcott [1908*d*, p. 59].
Obolus parvus Walcott [1908*d*, p. 61].
Acrothele colleni, new species.
Wimanella simplex Walcott [1908*d*, p. 101].
Agraulos, sp.
Ptychoparia, sp.
Bornemannia, sp.
Albertella bosworthi Walcott [1908*b*, p. 22].
Albertella helena Walcott [1908*b*, p. 19].
Vanuxemella contracta, new genus and new species.
Bathyuriscus, sp. a.

On Mount Stephen, at about the same horizon, the following were found:
Hyolithes billingsi Walcott [1886, p. 134].
Scenella varians Walcott [1886, p. 127].
Olenopsis agnes, new species.
Bornemannia prima, new genus and new species.

4. Interbedded layers of gray fossiliferous limestone and greenish gray siliceous shale.................................... 20

Fauna:
Nisusia festinata (Billings) [1861, p. 10].
Scenella varians Walcott [1886, p. 127].
Hyolithellus.

MOUNT WHYTE FORMATION (continued):

Feet

4 (continued):

Ptychoparia.
Agraulos.
Protypus fieldensis, new species.
Olenellus canadensis, new species.

At this horizon on Mount Stephen the following were found:

Micromitra (*Iphidella*) *pannula* (White) [1874, p. 6].
Acrotreta sagittalis taconica (Walcott) [1887, p. 189].
Kutorgina cingulata (Billings) [1861, p. 8].
Kutorgina, sp. undt.
Nisusia festinata (Billings) [1861, p. 10].
Hyolithes billingsi Walcott [1886, p. 134].
Scenella varians Walcott [1886, p. 127].
Protypus, new species.
Agraulos, sp. undt.
Ptychoparia, 3 sp. undt.
Olenellus canadensis, new species.

Bow River Group

ST. PIRAN FORMATION [Walcott, 1908*a*, p. 4]:

1*a*. Siliceous and arenaceous greenish-colored shales in layers 1 to 3 inches in thickness, interbedded in shaly and thin-bedded gray and brownish gray sandstone, with a thick layer of compact, gray sandstone near the top........................ 68

1*b*. Irregularly bedded brownish, dirty gray, and occasionally purplish-colored sandstones, more or less compact and quartzitic and in massive and thin layers that break down readily on slopes 310

Fauna:

Annelid trails and borings (*Scolithus*).
Hyolithes.
Olenellus canadensis ?, new species.
Ptychoparia (2 species).

1*c*. Massive bedded, compact, light gray and pinkish quartzitic sandstones 125

Fauna:

Annelid trails and borings (*Scolithus*).
Hyolithes.
Olenellus canadensis ?, new species (fragments).

The general dip of the strata is to the northwest 20°; strike, north 30° east. The section is continuous, with the exception of the displacement between the Paget and Bosworth formations of the Upper Cambrian. This does not cut out any considerable thickness of strata, as is proven by the unbroken section in the cliffs of Mount Daly three miles to the north.

In the Lakes Louise and Agnes section, about five miles southeast of Mount

Bosworth, the total thickness of the St. Piran formation is 2,705 feet. Below the St. Piran the following section occurs:

LAKE LOUISE FORMATION [Walcott, 1908*a*, p. 5]:

		Feet
1.	Compact, gray, siliceous shale	105

Fauna:
Annelid trails.
Cruziana.
Micromitra (*Iphidella*) *louise* Walcott [1908*d*, p. 56].

FAIRVIEW FORMATION [Walcott, 1908*a*, p. 5]:

1.	Thin and thick layers of gray, quartzitic, brownish weathering, compact sandstones (estimated)	600+

This formation is much thicker to the southeast.

RÉSUMÉ, MOUNT BOSWORTH SECTION

UPPER CAMBRIAN.

SHERBROOKE FORMATION:

		Feet	Feet
1.	Gray, partly cherty limestones	175	
2.	Oölitic limestones and shaly band	590	
3.	Arenaceous dolomitic limestone	610	
	Total		1,375

PAGET FORMATION:

1.	Massive bedded bluish gray limestone	60	
2.	Oölitic limestone with bands of shale	300+	
	Total		360+

BOSWORTH FORMATION:

1.	Gray, arenaceous, dolomitic limestone	600+	
2.	Shaly and thin-bedded, dolomitic limestones with two bands of shale	987	
3.	Shales	268	
	Total		1,855+
	Total Upper Cambrian		3,590+

MIDDLE CAMBRIAN.

ELDON FORMATION:

1.	Siliceous and arenaceous limestone	788	
2.	Bluish gray limestone	95	
3 and 4.	Arenaceous limestone	1,845	
	Total		2,728

PROFILE VIEW OF RIDGES SOUTHEAST (IN THE DISTANCE) AND WEST (FOREGROUND) OF LAKE LOUISE

The distant profile shows the Fairview formation at the base of Fairview Mountain. The Lake Louise formation is at (*a*), and from (*a*) to about (*b*) the St. Piran quartzitic sandstones. The Mount Whyte and Cathedral formations form the summits of the distant peaks. The quartzitic sandstones of the St. Piran formation are well shown on the ridge in the foreground.

RÉSUMÉ, MOUNT BOSWORTH SECTION (continued):

STEPHEN FORMATION:

	Feet	Feet
1. Thin-bedded, dark and bluish gray limestone	315	
2. Alternating limestones and shales	325	
Total		640

CATHEDRAL FORMATION:

1. Arenaceous dolomitic limestone		1,595
Total Middle Cambrian		4,963

LOWER CAMBRIAN.

MOUNT WHYTE FORMATION:

1. Thin-bedded limestones	224	
2. Sandstone	31	
3. Siliceous shale	115	
4. Gray limestone	20	
Total		390

ST. PIRAN FORMATION:

1. Sandy shales and quartzitic sandstones as exposed at Lake Agnes		2,705

LAKE LOUISE FORMATION:

1. Compact siliceous shale as exposed at Lake Louise		105

FAIRVIEW FORMATION:

1. Quartzitic sandstones as exposed at Lake Louise		600+
Total Lower Cambrian		3,800+

Upper Cambrian	3,590+
Middle Cambrian	4,963
Lower Cambrian	3,800+
Total thickness of sections examined	12,353+

Below the section of the quartzitic sandstones on Fairview Mountain there is, in the Bow River valley, a considerable, but unknown, thickness of sandstones and siliceous shales that have not been examined or measured.

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SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 53, NUMBER 6

CAMBRIAN GEOLOGY AND PALEONTOLOGY

No. 6.—OLENELLUS AND OTHER GENERA OF THE MESONACIDÆ

With Twenty-Two Plates

BY

CHARLES D. WALCOTT

(Publication 1934)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
AUGUST 12, 1910

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

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CONTENTS

INTRODUCTION

This paper was first planned to include the descriptions of the new genera and species of the Mesonacidæ that had been collected by me or under my direction since the publication of the memoir on the Olenellus fauna in 1891 [Walcott, 1891]. When the material was assembled, I wrote to my friend, Prof. Atreus Wanner, of York, Pennsylvania, asking if he had any new material. In response he sent me a beautiful series of specimens showing the growth of the dorsal shield of *Pædeumias transitans* and specimens of *Wanneria walcottanus* with a large spine on the fifteenth segment. I also found in the collections from central Alabama a very interesting series of specimens of the young cephalons of *Pædeumias* and *Wanneria.* The result has been that I have reviewed and discussed the family Mesonacidæ and illustrated the known genera and species more or less fully.

When in 1891 I proposed to use the term Mesonacidæ [Walcott, 1891, p. 635] I thought it a better selection than to propose Olenellidæ and so stated. Vogdes [1893, p. 254] evidently misunderstood my intention and used the term Olenellidæ. Later Moberg [1899, p. 316], evidently without knowing of Vogdes' use of the term, proposed to use Olenellidæ, as he thought it did not conflict with Olenidæ. Lindström [1901, p. 12] simply followed Moberg. The term Olenellidæ is a good one, but Mesonacidæ has priority, and also the genus *Mesonacis* is much more typical of the family than the genus *Olenellus;* the latter is the last phase of the evolution of one branch of the family, while *Mesonacis* illustrates the stage in which the marked characteristics of most if not all of the genera are present.

Mesonacis vermontana (Hall) was founded on a specimen preserving the cephalon and a portion of the thorax [Hall, 1859, fig. 2, p. 60]. In 1886 I found this form was essentially similar to *Olenellus thompsoni* [Walcott, 1886, pl. 24, fig. 1a] back to the fourteenth segment, but that the fifteenth segment instead of being a telson was a thoracic segment with a long median spine. Posterior to the fifteenth segment there were ten segments with short pleural lobes and a platelike pygidium [pl. 26, figs. 1 and 2]. For this strange form the genus *Mesonacis* was proposed [Walcott, 1885, p: 328], and I [Walcott, 1886, p. 166] concluded that the telson of *Olenellus thompsoni* was represented in *Mesonacis* by the fifteenth segment and the posterior segments and pygidium. Subsequently other specimens were found with segments posterior to the fifteenth [pl. 26, fig. 3], and one large specimen [see pl. 33, fig. 1, and pl. 24, fig. 12] that had

three very short rudimentary segments and a plate-like pygidium beneath the great spine on the fifteenth segment.[1] These specimens convinced me that *Olenellus thompsoni* passed through a *Mesonacis* stage before becoming a typical *Olenellus*. I put the specimens away in hopes that others would be found throwing more light on the problem. In the collection made by Dr. Charles Schuchert at York in 1896 an otherwise typical form of *Olenellus thompsoni* 40 mm. in length was found to have four rudimentary segments and a pygidium beneath the spine on the fifteenth segment, but it was not until 1909 when Prof. Atreus Wanner sent me a large series of specimens showing young stages of growth, also adults with from two to four rudimentary segments posterior to the fifteenth spine bearing segment that sufficient material was available to definitely conclude that *Olenellus thompsoni* passed through a *Holmia*, a *Mesonacis*, and a *Pædeumias* stage of development, and later became a typical *O. thompsoni* with a terminal telson by the absorption of certain rudimentary segments and a plate-like pygidium.

FUTURE WORK

It is exceedingly desirable that more collecting should be done in the Lower Cambrian formations of the Reval region of Russia; in Finland; and in the various localities in Sweden, Norway, and England. I am sure that important information in relation to the Mesonacidæ would be secured by a systematic search for more and better material. In America we will continue the work in 1910 in western Newfoundland and the Straits of Belle Isle, and in British Columbia and Alberta, and another season will be spent in Nevada and California.

ACKNOWLEDGMENTS

I am greatly indebted to Prof. Atreus Wanner, Superintendent of Public Schools at York, Pennsylvania, for very generously permitting me to study and illustrate the material in his collection.[2] Prof. H. Justin Roddy, of the State Normal School at Lancaster, Pennsylvania, permitted me to examine the collection he had made in Lancaster County, and loaned me specimens, and both he and Professor Wanner took me over the areas from which they collected specimens in central Pennsylvania. Dr. Joh. Chr. Moberg, of the

[1] This form is now included in *Pædeumias transitans*.

[2] Professor Wanner has since presented to the United States National Museum the specimens illustrated and described in this paper.

University of Lund, Sweden, sent me casts and specimens of the species described by him. Dr. B. N. Peach most kindly guided me to the Loch Maree localities in northwest Scotland and, by the permission of the Director of the Geological Survey of Great Britain, Dr. J. Horne, in charge of the Scottish Survey, sent me the material in the collections of the Geological Survey and the Royal Scottish Museum at Edinburgh. Mr. Frank Raw of the University of Birmingham sent me photographs and plaster casts of the specimens described by him from the Comley sandstone of Shropshire, England.

Dr. John M. Clarke, of the New York State Survey, loaned me the Ford specimens of *Elliptocephala asaphoides*, and Prof. George H. Perkins, State Geologist of Vermont, sent me the material in the State Survey collections from western Vermont. The Director of the Geological Survey of Canada kindly loaned the specimens in the Survey Museum.

Among the collectors who have assisted in obtaining the material studied I wish to mention Mr. William P. Rust, of Trenton Falls, New York, and Dr. Cooper Curtice, of Moravia, New York, both of whom worked in the town of Georgia, Vermont, and in Washington County, New York. Also Mr. F. B. Weeks, Mr. Henry Dickhaut, and Mr. T. E. Williard, of the U. S. Geological Survey.

The material of value from Alberta and British Columbia was principally collected by Mrs. Walcott and myself during the summer of 1909.

To all I return my sincere thanks, and if I have omitted to mention any who may have given assistance I trust that they will accept an apology for my unintentional neglect.

Order OPISTHOPARIA Beecher

Order *Opisthoparia* Beecher, 1897, American Journ. Sci., 4th ser., Vol. 3, p. 187. (Defined as below.)

"Free cheeks generally separate [but not in the Mesonacidæ], always bearing the genal angles. Facial sutures [when not in a state of synthesis] extending forwards from the posterior part of the cephalon within the genal angles, and cutting the anterior margin separately, or rarely uniting in front of the glabella. Compound, paired holochroal [?] eyes on free cheeks [or corresponding portion of cephalon], and well developed in all but the most primitive family."

The words enclosed in brackets I have added to Dr. Beecher's definition of the order.

Family MESONACIDAE[1] Walcott

Mesonacidæ Walcott, 1891, Tenth Ann. Rept. U. S. Geol. Survey, p. 635. (Cites *Olenellus* (*Mesonacis*) *vermontana* as typical of the family. Declines to propose term *Olenellidæ* as it was too much like the family name *Olenidæ*.)

Olenellidæ Vogdes, 1893, Occasional Papers California Acad. Sci., 4, p. 254. (Cites *Olenellus thompsoni* Hall as the type.)

Olenellidæ Moberg, 1899, Geol. Fören. i Stockholm Förhandl., Bd. 21, Häfte 4, p. 316. (The author includes under this family name the following species: *Georgiellus* (*Elliptocephala*) *asaphoides* (Emmons), *Olenellus thompsoni* Hall, *Holmia kjerulfi* (Linnarsson), *Mesonacis vermontana* (Hall), *Mesonacis mickwitzi* (Schmidt), and *Olenelloides armatus* Peach.)

Olenellidæ Lindström, 1901, Kongl. Svenska Vet.-Akad. Handlingar, Vol. 34, No. 8, p. 12. (Uses *Olenellidæ* as a group name for the "*Olenellidæ* proper" and the *Paradoxinæ*.)

Description.—Cephalon very large, wider than long, genal angles with spines; intergenal spines developed in young and may be present in adult. Facial suture rudimentary, or in a condition of synthesis. Eyes crescentic or semicircular and attached more or less closely to the anterior lobe of the glabella by a rounded ridge; visual surface of eyes with facets arranged in quincunx order. Hypostoma usually with more or less spinose posterior margin. Thorax long, composed of from 13 to 27 free segments. Pygidium small, margin usually entire but may have from one to three spines. Surface of test in adult specimens granular and usually with network of very fine thread-like raised inosculating ridges.

The genera included are *Nevadia, Mesonacis, Elliptocephala, Callavia, Holmia, Wanneria, Pædeumias, Olenellus, Peachella,* and *Olenelloides.*

OBSERVATIONS—DEVELOPMENT

Cephalon.—The youngest stage of growth known to me is the Protaspis stage of *Elliptocephala asaphoides* [pl. 25, fig. 9]. In this the palpebral ridges are continuous with the transversely elongated anterior lobe of the glabella and arch about the spaces between the glabella and the eye lobe, and continue back across the posterior border of the cephalon. The segmentation of the cephalon is beautifully shown by figs. 9, 10, and 22, pl. 25. In figs. 9 and 10 the occipital segment merges into the strong ridge and spine formed by the next two anterior segments; the fourth anterior segment curves

[1] The genus *Mesonacis* is more typical of the family than the genus *Olenellus* and as Mesonacidæ was first used, I shall continue it in this paper.

back against the palpebral ridge, and the latter, with the occular segment, terminates against the large intergenal spine formed by the prolongation of the glabellar segments. The pygidium is a simple plate without axis or traces of segmentation. The young of *Pædeumias transitans* [pl. 25, fig. 22] of a little later stage of growth has the segmentation of the cephalon finely shown, also remarkably long, intergenal spines.

The progressive changes of the cephalon result in the gradual separation of the intergenal and genal spines and the straightening out of the posterior margin. This occurs in *Pædeumias* [pl. 25, figs. 20-22], *Elliptocephala* [pl. 25, figs. 9-12], and *Wanneria* [pl. 31, figs. 8, 7, 5, and 6]. A curious phase in the later development of the cephalon is the advancing of the genal angles from the line of the occipital segment until they are forward of the anterior margin of the glabella. [See pl. 32 for *Pædeumias,* pl. 25 for *Elliptocephala,* pl. 31 for *Wanneria,* and pl. 37 for *Olenellus.*]

The genal, intergenal, and antero-lateral spines of the cephalon undoubtedly represent the pleural ends of segments that have been fused together and greatly modified in the process. The genal spines persist in the adult of the Mesonacidæ and often the intergenal spines, but only in a modified manner. The intergenal spines are seen in a later geological period in the adult *Bronteus,*[1] where they might be considered as a reversion to a character of their Cambrian ancestors. *Hydrocephalus*[2] appears to have an intergenal spine and in all of the *Proparia* [Beecher, 1897, p. 198] the "genal spine" is attached to the space within the facial sutures, and is in fact the prolongation of one of the fused segments of the cephalon, and corresponds in this respect to the intergenal spine of the Mesonacidæ. Some of the species of the genus *Agnostus* also show spines that suggest the intergenal spine, notably *A. granulatus* Barrande and *A. rex* Barrande.[3]

Number of segments in the cephalon.—The question of the number of segments represented in the cephalon is one that cannot be fully discussed here.[4] The presence of a palpebral segment that appears to also form the larger part of the anterior glabellar lobe

[1] Barrande, 1872, pl. 9, figs. 12 and 13; and pl. 11, figs. 13 and 14.

[2] Barrande, 1852, pl. 49.

[3] Barrande, 1852, pl. 49.

[4] The student is referred to a paper by H. M. Bernard on the "Systematic Position of the Trilobites," Quart. Journ. Geol. Soc., London, Vol. 50, 1894. pp. 411-432; also to C. E. Beecher's paper on the "Larval Stages of Trilobites," American Geologist, Vol. 16, 1895, pp. 166-197.

in the young of *Elliptocephala* [pl. 25, figs. 9 and 10], *Pædeumias* [pl. 25, fig. 22], and *Olenellus* [pl. 36, figs. 11-14], and the posterior portion of the same lobe in *Olenellus logani* [pl. 41, fig. 6], is evidence that there are six, if not seven, clearly defined segments in the cephalon; these include the occipital ring, the four segments represented by the glabellar lobes, and the occular or eye-bearing segment; the expansion of the latter may form the anterior portion of the first glabellar lobe as indicated in *Olenellus logani* [pl. 41, fig. 6], where the furrows on the glabella in advance of the palpebral segment apparently outline the segment. In all trilobites where the cheeks carry the visual surface of the eye, the cheeks may be considered as an expansion of the occular segment, and probably of a segment in advance of it, and the genal spines are the outward termination of the occular segment. The anterior and second segments of the glabella do not appear to terminate in spines, but the third or fourth segment may be extended into the intergenal spines [pl. 25, figs. 9, 10, and 22; pl. 39, fig. 6].

It is not improbable that a seventh segment more anterior than the occular segment existed in the primitive cephalon of the Mesonacidæ; this is indicated by the antero-lateral spines of the young of *Olenellus gilberti* [pl. 36, figs. 11-14] and the larval-like cephalon of *Olenelloides* [pl. 40, figs. 2 and 3] and by the cephalon of *Callavia bicensis* [pl. 41, fig. 9] where there are two pairs of furrows in front of the palpebral ridge.

The preceding brief outline of the segments included in the cephalon may be tabulated as follows:

1. Anterior border segment, the reflected margin of which supports the hypostoma.

2. Occular segment carrying the visual surface of the eye.

3. Palpebral or first glabellar segment from which the large anterior lobe of the glabella was largely developed, also the so-called "occular" ridge, and the palpebral lobe.

4. Second glabellar segment which is usually extended beyond the end of the third glabellar segment in the adult cephalon.

5. Third glabellar segment which may or may not be extended so as to appear in the interpalpebral space.

6. Fourth glabellar segment. This segment in the young [pl. 25, figs. 9, 10, 13, and 22; pl. 36, fig. 12] may be continued as an intergenal spine.

7. Occipital segment, the extensions of which terminate against the intergenal spines [pl. 25, figs. 9, 10, and 22].

Eye.—The changes in the eye lobes vary in different genera. All agree in having a proportionally very long eye lobe in the youngest stages, such as those represented by figs. 9 and 10, pl. 25, of *Elliptocephala;* figs. 20-22, pl. 25, of *Pædeumias,* and figs. 5-8, pl. 31, of *Wanneria.* The elongated eye lobes remain during life in most of the species of all of the genera, excepting *Wanneria.* In this latter genus the eye lobe is very long in the young [pl. 31, figs. 8, 7, 5, and 4] and short in the adult [pl. 31, figs. 1, 3; pl. 30, figs. 1 and 2]. Two species of the genus *Olenellus* have short eye lobes: *O. fremonti* [pl. 37] and *O. canadensis* [pl. 38]. The eye of *O. fremonti* is unique in that it is larger in the adult [pl. 37, figs. 1, 2, 3, and 6] than in the young stages of growth [figs. 8-12]. This is one of the characters that leads me to consider that the species is one that is descendent from a species that had attained, as far as the eye was concerned, the most advanced stage of development of any species of the Mesonacidæ, and then through reversion developed the long eye lobe in the adult. This stage might be represented by the small-eyed *O. canadensis.*

In one species I have been so fortunate as to find the outer faceted surface preserved [pl. 43, figs. 5 and 6]. This surface is perforated by minute rounded, hexagonal openings arranged in oblique transverse rows which gives them a more or less quincunx order. The interstitial spaces between the openings are narrow, rounded ridges. There is no trace of a corneal covering, and the surface is so much like that of the outer surface of the eye of *Limulus* that I cannot avoid the conclusion that they are of the same type [compare figs. 4 and 5, pl. 43], and "inward projections of the outer cuticle" [Bernard, 1894, p. 422]. Bernard concludes that the eye of *Limulus* is more primitive than that of *Apus.* This may be a correct view, but I strongly suspect that the primitive phylopods of the type of *Apus* will be found to have developed earlier than the trilobites.

Dr. A. S. Packard [1880, p. 508], after comparing the eye of *Limulus* with the sections of the eye of some Ordovician trilobites, notably *Asaphus* and *Bathyurus,* came to the conclusion that the hard parts of the eye of the trilobites and of *Limulus* were throughout identical, and that the trilobite's eye was organized on the same plan as that of *Limulus.* Dr. G. Lindström, in his Researches on the Visual Organs of the Trilobites [1901, pp. 26-27], found that there were several types of eyes among the trilobites:

I. Genera with compound eyes having:
(a) prismatic plano-convex cornea facets;
(b) round or bi-convex transversely elongate lenses;
II. Genera with aggregate eyes of bi-convex lenses; and
III. Genera with isolated eyes, one or several stemmata at the extremity of a straight facial ridge.

He says [1901, p. 27] of the statement of Packard: "This statement is altogether wrong, and as I hope to show the trilobites have had eyes entirely different from those of *Limulus,* and instead agree with those of the *Isopoda* and perhaps also with a few other Crustacea."

At the time Dr. Lindström wrote he was unacquainted with the visual surface of the eye of *Olenellus* and contended [1901, p. 9] that all Cambrian trilobites were blind in not having eyes on the upper surface of the cephalon. He thought that they might have been provided with visual organs on the hypostoma. The discovery of the faceted surface of the eye of *Olenellus gilberti* clearly negatives the broad conclusion of the absence of a visual organ on the upper surface of the cephalon and indicates that with sufficiently well-preserved specimens the visual surface will be found on all Cambrian trilobites with eyes. That it has not been found long ago is probably due to the fact that the roughened visual surface without a corneal covering adheres to the matrix and is broken off with it. I do not wish to assert that the eyes of *Olenellus* and *Limulus* are constructed on the same plan, but I do think that the outward appearance of the surface of the eye of the young specimens shows that they were similar [pl. 43, figs. 4 and 5].

Dr. Lindström [1901, p. 71] found maculæ on the hypostoma of 136 species of 39 genera of trilobites, on 36 species of which it was possible to study the structure of the maculæ through sections. He states that while the structure that often characterizes the maculæ as a visual organ is very rudimentary, there is no doubt that it subserved the purpose of the visual organ, even where there is no trace of any definite structure that is preserved in the fossil state. In final conclusion he says [1901, p. 74]:

We find the maculæ of the trilobites present from the oldest Cambrian times and we find also in them a progressive evolution, in some to a high degree, lenses and facets, perfectly identical with those of the eyes on the head shield, converting them into true eyes. . . . . But there are, no doubt, still more facts to adduce for filling up extant lacunæ in the knowledge of these matters.

I have not been able to find maculæ showing any definite structure on the hypostoma of any species of the Mesonacidæ. I see, however, no *a priori* reason why such structures should not be present.

From the structure and probable habits of the trilobite, as a mud-burrowing animal more or less allied to *Limulus,* it does not at first appear what special purpose was subserved by having visual organs on the hypostoma. While thinking of this, I was led to revert to observations that I made when collecting trilobites showing ventral appendages. These notes [Walcott, 1875, p. 159] state that of 1,160 specimens of *Ceraurus* noted on the under surface of a thin layer of limestone, 1,110 were lying on their backs when buried in the sediment and but 50 presented the dorsal surface upward. Prof. Alexander Agassiz in describing the habits of young *Limulus* says [1878, pp. 75-76]:

Mr. C. D. Walcott has called attention to the fact that when collecting fossils he finds large numbers of trilobites on their back[1]; from this he argues that they died in their natural position, and that when living they probably swam on their backs. He mentions, in support of his view, the well-known fact that very young *Limulus* and other crustacea frequently swim in that position. I have for several summers kept young horse-shoe crabs in my jars, and have noticed that besides thus often swimming on their backs, they will remain in a similar position for hours, perfectly quiet, on the bottom of the jars where they are kept. When they cast their skin it invariably keeps the same attitude on the bottom of the jar. It is not an uncommon thing to find on beaches, where *Limulus* is common, hundreds of skins thrown up and left dry by the tide, the greater part of which are turned on their backs. An additional point to be brought forward to show that the trilobites probably pass the greater part of their life on their back, and die in that attitude, is that the young *Limulus* generally feed while turned on their back; moving at an angle with the bottom, the hind extremity raised, they throw out their feet beyond the anterior edge of carapace, browsing, as it were, upon what they find in their road, and washing away what they do not need by means of a powerful current produced by their abdominal appendages.

My object in calling attention to the above facts in relation to the habit of trilobites and *Limulus* is to suggest that in all probability the eyes of the hypostoma were of service when the trilobite was lying on its back on the sand or mud, and it was on this account that they were thus developed. It is highly probable that the adult trilobite crawled about the bottom and did not swim freely in the water to the extent that it would be necessary for it to be able to see the bottom. Its habits must have been very much like those of *Limulus* when in search of food. That the trilobite burrowed and pushed

[1] Ann. Lyceum Nat. Hist. New York, Vol. 11, 1875, pp. 155-159.

its way through the mud and soft sands in a manner similar to that of *Limulus* is proven by the trails and burrows left by it which we now designate as *Cruziana* [Walcott, 1891, pls. 64-66].

Facial sutures.—The facial sutures are rarely represented, even by elevated lines on the exterior surface or depressed lines on the interior surface of the cephalon. If we accept Beecher's view that the sutures are in a condition of symphysis [Beecher, 1897, p. 191], and that the elevated and depressed lines represent the suture between the cranidium and free cheeks, the latter bear the visual surface of the eye. In my hurried study of the *Olenellus* fauna in 1886 and 1891 I permitted facial suture lines to be represented in front of the eye in a specimen referred to *Olenellus gilberti* [Walcott, 1886, pl. 20, fig. 1*h;* 1891, pl. 86, fig. 1*h*] on evidence that now appears to me to be insufficient, as the line may have been formed by a fracture in the test.

In one specimen of *Pædeumias transitans* [pl. 33, fig. 1] an elevated line having the usual curvature of the posterior facial suture starts from the base of the eye at its posterior third and extends with a gentle sigmoid curve outward and backward to the postero-lateral angle of the cheek where it fades away. It is not probable that this line represents the facial suture that has been lost in the development of the cephalon, but it suggests that conclusion.

Prof. R. P. Whitfield [1884, p. 151, pl. 15, fig. 1] describes and illustrates the curve of facial sutures in *Olenellus thompsoni.*[1] The curve assigned to the sutures back of the eye is certainly incorrect, as, from many specimens, we know that the elevated lines run to the intergenal angles, and I strongly suspect that the suture as outlined in front of the eye is based on a crack in the test, as the specimen is flattened in the arenaceous shale.

Anterior glabellar lobe.—The anterior or first lobe of the glabella in the young stages of growth is small and a part of the palpebral segment of the cephalon [pl. 25, figs. 9, 10, and 22]. In what I consider to be the most primitive genus of the Mesonacidæ, *Nevadia* [pl. 23], the first lobe is small and not at all expanded as in *Olenellus* [pl. 37]. In *Callavia* [pls. 27 and 28] the first lobe is also small, although the genus occurs at a much higher horizon than *Nevadia.* We find that *Holmia weeksi* [pl. 29] which is associated with *Nevadia* has an expanded first glabellar lobe. That the small, contracted first lobe of *Nevadia* is a primitive character is shown by its occurring in the youngest stages of growth of all the genera of

[1] Referred in this paper to *Pædeumias transitans.*

the Mesonacidæ of which we have the young cephalon. The small first glabellar lobe of *Callavia* is an illustration of the survival of a primitive character in the adult of a later genus or it may be an instance of reversion to a primitive character. The anterior glabellar lobe of *Pædeumias* [pl. 34] and *Olenellus* [pls. 34-39] is expanded and convex when found in a matrix favorable to preserving the convexity. Most specimens have been found in shales which accounts for the flattening of the lobe and the fracturing of the test not only of the lobe but of the adjoining parts of the cephalon. The expansion of the anterior lobe of the glabella in the genera *Mesonacis, Elliptocephala, Holmia, Wanneria, Pædeumias,* and *Olenellus* indicates that these genera are of later origin than *Nevadia,* and this conclusion is strengthened by the evidence afforded by a comparison of the thorax of the genera. *Callavia* has the primitive glabella, but its thorax indicates a later origin than the genera *Nevadia, Mesonacis,* and *Elliptocephala.*

Another interesting character of the anterior lobe is the presence in *O. logani* [pl. 41, fig. 9] of a faint furrow that extends inward a short distance from the point where the anterior margin of the palpebral ridges joins the anterior glabellar lobe; this pair of furrows indicates that the lobe is formed of two segments of the original primitive cephalon.[1] The palpebral segment is beautifully shown by the young of *Elliptocephala asaphoides* [pl. 25, figs. 9 and 10].

Hypostoma.—The hypostoma has a convex central body that is narrowed posteriorly by grooves that separate the body from a transverse posterior portion on which maculæ may be present. It may be attached directly to the anterior doublure of the cephalon or by a narrow process [pl. 34, figs. 5-7]. Minute specimens of the hypostoma of *Wanneria halli* [pl. 31, fig. 9] show a perforated, flattened marginal border on the posterior and postero-lateral sides. As the hypostoma increases in size the outer rim disappears and the test between the lobes forms a denticulated margin as in *Pædeumias transitans* [pl. 34, fig. 7]. The next development is the absorption of the thickened points and the formation of true spines [pl. 34, fig. 5]. This type of hypostoma is found in *Elliptocephala asaphoides* [pl. 24, fig. 8], *Holmia kjerulfi* [pl. 27, fig. 7], *Wanneria halli* [pl. 31, fig. 9], *Pædeumias transitans* [pl. 34, figs. 5 and 6], *Olenellus gilberti* [pl. 36, fig. 5], *Olenellus fremonti* [pl. 37, figs. 21 and 22],

[1] This anterior pair of furrows is shown for *Paradoxides* by Barrande's illustrations of *P. spinosus* [Barrande, 1852, pl. 12, figs. 2, 3, and 6; and pl. 13, fig. 1] and *P. pusillus* [Barrande, 1872, pl. 9, fig. 23].

Olenellus lapworthi [pl. 39, fig. 7], and *Olenellus claytoni* [pl. 40, fig. 9].

The absorption of the spines and the resultant smooth margin appears to have been accomplished in *Callavia bröggeri* [pl. 27, fig. 2], *C. crosbyi* [pl. 28, fig. 6], *Olenellus canadensis* [pl. 38, figs. 2 and 3], *Holmia lundgreni* [pl. 40, fig. 6], and *Mesonacis torrelli* [pl. 26, figs. 9 and 10].

The hypostoma of *Olenellus* has the maculæ clearly indicated, but none of the specimens are sufficiently well preserved to permit of making thin sections to determine its structure.

Thorax.—As shown by adult specimens, the development of the thorax from *Nevadia* to *Olenellus,* inclusive, may be divided into six stages.

1. *Nevadia stage:* In *Nevadia* the thoracic segments of a uniform character follow each other from the first to the seventeenth. At the eighteenth segment an abrupt change occurs [pl. 23, figs. 1, 2, and 4]. The grooved pleural lobe disappears and a spinose extension of the same general character as that attached to the anterior pleural lobes is attached directly to the side of the axial lobe of the posterior eleven segments. The dorsal shield is terminated by a very small and simple pygidium.

2. *Mesonacis stage:* In *Mesonacis* [pl. 26, fig. 1] the thoracic segments are fully developed from the first to the fourteenth. The third segment is enlarged and the fifteenth segment has a large median spine and the ten posterior segments form a distinct subordinate series of small but typical segments. The smaller posterior segments are more advanced in development than the posterior segments of *Nevadia,* but not as much so as the anterior segments anterior to the fifteenth segment.

3. *Elliptocephala stage:* In *Elliptocephala* the third segment is relatively larger during the earlier stages of growth in which it has been observed [pl. 24, figs. 3-5], but this disappears in the adult [pl. 24, fig. 1], leaving the segments of a uniform character back to the fourteenth where there is a series of five short segments with long median spines. Most of the series of small segments of *Nevadia* and *Mesonacis* have disappeared.

4. *Holmia stage:* In *Holmia* the 16 segments are in orderly succession and of a similar character; the pygidium remains relatively small and more or less rudimentary. This is best shown by *Holmia kjerulfi* [pl. 27, fig. 7] and *H. rowei* [pl. 29, figs. 3 and 4]. In *Wanneria walcottanus* a short, slender spine appears on the four-

teenth segment in fully matured dorsal shields [pl. 30, figs. 10-12]; otherwise the segments are of the same character, except as they decrease uniformly in size to the pygidium. In *Callavia bröggeri* [pl. 27, fig. 1] the seventeenth and eighteenth segments are relatively smaller, in this respect resembling the shorter posterior segments of *Mesonacis* and *Elliptocephala*.

5. *Pædeumias stage:* In *Pædeumias transitans* [pl. 33] we find the transition stage between the stages represented by *Mesonacis* [pl. 26], *Elliptocephala* [pl. 24], and *Olenellus thompsoni* [pl. 35]. There are fourteen fully developed segments with the third segment enlarged and the fifteenth segment developed into a strong, long spine with the pleural lobes of the segment absent. Beneath and back of the large spine there are from two to six rudimentary segments without pleural lobes, and a simple plate-like pygidium.

6. *Olenellus stage:* Fourteen fully developed segments, a large third segment, and the fifteenth segment a strong terminal telson; posterior rudimentary segments and true pygidium of the *Pædeumias* stage absorbed [pl. 35, fig. 1] or the rudimentary segments and pygidium have disappeared and the large median spine of *Pædeumias* has become the telson of *Olenellus*.

Olenellus is the last genus of the *Olenellus* branch of the Mesonacidæ to develop, and from *Pædeumias transitans* we find evidence that it has passed through the *Holmia* stage [pl. 32, figs. 2 and 3] and the *Pædeumias* stage [pl. 33] before becoming a true *Olenellus*.

The enlarged third segment of *Olenellus* [pl. 35, fig. 1] also occurs in *Mesonacis* [pl. 26, fig. 1] and in the younger stages of growth of *Elliptocephala* [pl. 24, figs. 3-5]. In *Olenelloides* [pl. 40, fig. 3] both the third and sixth segments are enlarged. The cause of the enlargement and prolongation of the third segment is unknown. In *Paradoxides* the pleuræ of the second segment are elongated in small specimens of several species [Barrande, 1852, pl. 10, fig. 25; pl. 12, figs. 5-7; and pl. 13, fig. 16].

Peachella.—We know nothing of the thorax of *Peachella* [pl. 40, figs. 17-19], but from the cephalon it is probable that it was of the *Olenellus* type.

Olenelloides.—The thorax and large cephalon of *Olenelloides* [pl. 40, fig. 3] indicates a degenerate type and a stage of growth beyond which the animal could not develop. For the present it may be placed as a degenerate of the *Olenellus* stage of development.

Pygidium.—The pygidium is a simple transverse plate in the protaspis stage and it is not strongly developed in any genus and

species of the Mesonacidæ. It is very small, essentially rudimentary, and its segmentation is limited to one transverse ring on the median lobe [pl. 29, fig. 11].

The telson of *Olenellus* is not considered to be a true pygidium. It resembles the telson of *Limulus,* but this resemblance does not necessarily indicate that *Olenellus* was the ancestor of *Limulus;* its origin does, however, indicate the manner in which the telson of *Limulus* may have originated.

DELIMITATION OF GENERA

The cephalon in all genera of the Mesonacidæ is so nearly similar that only specific differences appear to be present, except in *Nevadia* and *Callavia,* which have a small anterior glabellar lobe. The modifications of the thorax are largely taken as the basis for generic separation. The pygidium is essentially the same in all of the genera.

Nevadia.—*Nevadia* [pl. 23] is characterized by the presence of small, simple segments (primitive segments) on the posterior portion of the thorax that have not been developed to the same degree as the segments anterior to them. In the type *Nevadia weeksi* the posterior eleven primitive segments have only the axial lobe and a spinose continuation on each side [pl. 23, figs. 1, 2, and 4]; the grooved pleural lobe of the seventeen more specialized anterior segments is not present. The spinose extensions of the posterior segments are proportionally much rounder and smaller than those of the anterior seventeen segments. As far as known the posterior thoracic spines of *Elliptocephala* [pl. 24, figs. 1 and 9] and the great spine of the fifteenth segment of *Wanneria* [pl. 30, fig. 11] and *Mesonacis* [pl. 26, fig. 1] were not developed in *Nevadia.*

The only species referred to *Nevadia* is *N. weeksi* Walcott.

Mesonacis.—This form [pl. 26, fig. 1] is essentially the same as *Elliptocephala,* but it has an enlarged third segment in the adult and a strong spine on the fifteenth segment. The posterior contracted segments are also of a different character. In *Mesonacis* they are similar to those anterior to the fifteenth segment, while in *Elliptocephala asaphoides* they lose the long-curved pleura so characteristic of the anterior thirteen segments.

The posterior ten segments may be said to be [pl. 26, figs. 1, 2, and 3] less developed, proportionally than the anterior segments, although possessing a well-defined furrowed pleural lobe. A trace of this character is also preserved in *Callavia bröggeri* [pl. 27, fig. 1] where the two posterior thoracic segments are proportionally smaller than the anterior segments.

The species referred to *Mesonacis* are: *M. vermontana* (Hall), *M. mickwitzi* (Schmidt), and *M. torrelli* (Moberg).

Elliptocephala.—In *Elliptocephala* [pl. 24, figs. 1, 2, and 9] the posterior five segments are more highly developed than the primitive segments of *Nevadia,* but not as much so as the segments anterior to them. The abrupt narrowing of the thorax of *Elliptocephala* is of the same type as that shown by *Mesonacis* [pl. 26, fig. 1], but it does not have the large third segment in the adult stage or the great spine on the fifteenth segment.

The one species referred to *Elliptocephala* is *E. asaphoides* Emmons.

Callavia.—*Callavia* [pl. 27, fig. 1; pl. 28, figs. 4 and 8] has a trace of the constricted pleuræ of the posterior portion of the thorax in the two last segments; these are of the same type as the anterior segments. The broad thorax of *Callavia* with the falcate extensions of the pleuræ are quite unlike the narrow thorax of *Holmia* [pl. 27, fig. 7] with its spinose pleural extensions. There are differences of importance in the cephalon as compared with *Holmia.* The glabella of *Callavia* is narrower and more primitive and its intergenal spine is less primitive. The pleural furrow of *Callavia* is narrow and oblique like that of *Paradoxides,* while the pleural furrow of *Holmia* and *Wanneria* [pl. 30] is broad and straight like that of all other known genera of the Mesonacidæ. It is doubtful if *Callavia* should precede *Holmia,* but from its primitive glabella and the retaining of two shortened thoracic segments it appears to be nearer *Elliptocephala* than does *Holmia.*

The species referred to *Callavia* are: *C. bicensis* Walcott, *C. bröggeri* (Walcott), *C. burri* Walcott, *C. callavei* (Lapworth), *C. cartlandi* (Raw), *C. crosbyi* Walcott, and *C. nevadensis* Walcott.

Holmia.—*Holmia* [pl. 27, fig. 7] with its uniform series of segments and simple plate-like pygidium appears to represent a stage in the development of the Mesonacidæ that followed the *Elliptocephala-Mesonacis* stages. It has lost the rudimentary thoracic segments of *Nevadia,* it is without the large third segment of the adult *Olenellus* and *Mesonacis,* and it is not known to have had an enlarged third segment at any stage of growth. The posterior segments do not show the restricted character of those posterior to the fifteenth spine bearing segment of *Mesonacis,* or the rudimentary form of the posterior segments of *Pædeumias.*

The species referred to *Holmia* are: *H. kjerulfi* (Linnarsson), *H. lundgreni* (Moberg), and *H. rowei* Walcott.

Wanneria.—*Wanneria* [pl. 30] has a uniform series of thoracic segments with the pleuræ terminating in broad falcate extensions beyond the body line [pl. 30, fig. 1] instead of spinose ends as in *Holmia* [pl. 27, fig. 7]. It has a great median spine on the fifteenth segment, much like that of *Mesonacis* [pl. 26, fig. 1] and *Pædeumias transitans* [pl. 33]. The posterior segments are not rudimentary as in the latter species. For comparison with *Callavia* see above.

The species referred to *Wanneria* are: *W. walcottanus* (Wanner), *W. gracile* Walcott, and *W. halli* Walcott.

Pædeumias.—The posterior rudimentary thoracic segments of *Pædeumias transitans* [pl. 33] appear to be the result of the absorption of the posterior segments of a many segmented ancestor and are unlike the rudimentary posterior segments of *Nevadia,* which I think are the originally less developed segments and which record a stage in the early evolution of the Mesonacidæ that has not been found in any other known species. The pygidium is also rudimentary. The distinctive characters of the genus are in the presence of the rudimentary segments and pygidium.

The only species referred to *Pædeumias* is *P. transitans* Walcott.

Olenellus.—That *Olenellus* [pls. 37-39] should result from the great development of the median spine on the fifteenth segment and the absorption of the posterior rudimentary segments and pygidium of its *Mesonacis* stage of development [pl. 33] is of great interest, as it proves it to be the last phase of development of this line of the Mesonacidæ. *Olenellus thompsoni* passes through a *Holmia* [pl. 32, figs. 1-3] and *Pædeumias* stage [pl. 33] before becoming a true *Olenellus.*

The American species referred to *Olenellus* are: *O. thompsoni* Hall and its variety *crassimarginatus* Walcott, *O. gilberti* Meek and an undetermined variety, *O. fremonti* Walcott, *O. canadensis* Walcott, *O. claytoni* Walcott, *O. argentus* Walcott, and *O. walcotti* (Shaler and Foerste).

The European species are: *O. gigas* Peach, *O. lapworthi* Peach, *O. reticulatus* Peach, and *Olenellus* 2 sp. undt.

Peachella.—*Peachella* [pl. 40, figs. 17-19] is known only by its cephalon. This indicates a type related to *Wanneria gracile* [pl. 38, figs. 21 and 22] or the younger stages of growth of *Olenellus canadensis* [pl. 38, fig. 6]. It is probable that the thorax and pygidium will be found to be much like that of *Olenellus.*

The only species known is *P. iddingsi* (Walcott).

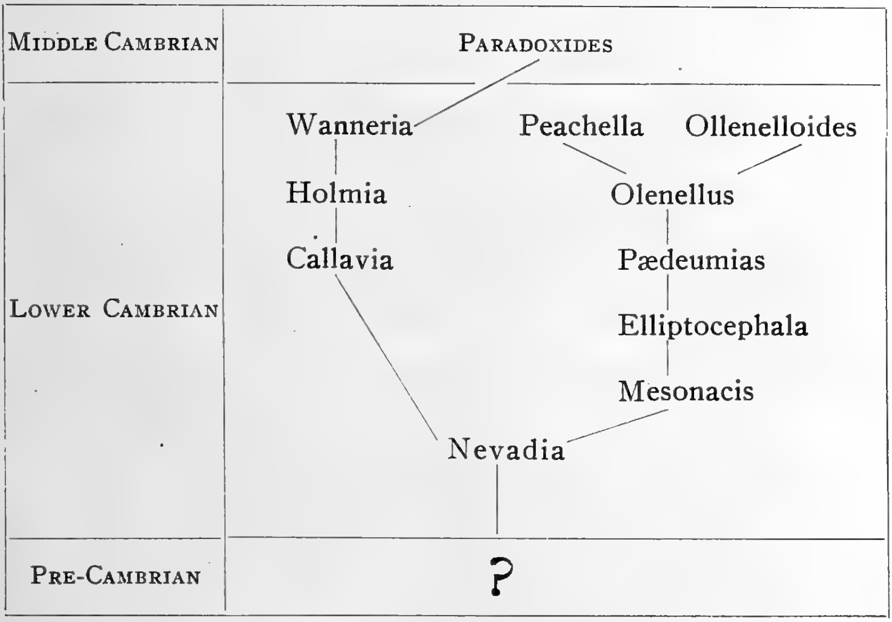
Olenelloides.—*Olenelloides* is clearly defined by its large cephalon and primitive thorax and pygidium.

DEVELOPMENT OF MESONACIDÆ

The development of the Mesonacidæ from some annelidian-like ancestor by the gradual combination of segments to form the cephalon and pygidium is indicated by the examples cited of *Nevadia, Elliptocephala, Holmia,* and *Pædeumias.* The cephalon, as we know it, was developed in pre-Cambrian time, also the pleural lobes of the thorax. The compact, strong pygidium, made up of many segments, does not occur in the Mesonacidæ, and is unknown in any trilobite from the beds of the Lower Cambrian in which the simplest form of the Lower Cambrian trilobites (*Nevadia weeksi*) occurs.

With my present information I am inclined to think that *Paradoxides* descended through the *Callavia-Wanneria* line, rather than the *Mesonacis-Olenellus* line. The latter line expended its force and became extinct in Lower Cambrian time, leaving no descendant to pass into the Middle Cambrian.

Diagrammatically represented my present conclusion as to the development of the known genera of the Mesonacidæ is as follows, beginning with *Nevadia* at the base.



The presence of a *Holmia*-like species (*H. rowei*) with *Nevadia* in the oldest known horizon of the Mesonacidæ indicates that more primitive forms of the *Nevadia* type existed at an earlier epoch before *Holmia* was developed by the absorption of the simple posterior segments of its *Nevadian* progenitor.

Mesonacis occurs in association with *Olenellus,* but I think that *Mesonacis*-like forms developed at an early epoch and that *Mesonacis vermontana* is a survival of a stage in the evolution of *Olenellus* that preceded *Elliptocephala* and *Pædeumias*. One of the conclusions resulting from this study of the Mesonacidæ is that we know only a few of the representatives of the family, and of these only a very few showing the younger stages of growth, and the entire dorsal shield.

MESONACIDÆ AND PARADOXINÆ

The family Mesonacidæ is distinguished from the Paradoxinæ mainly by the presence in the latter of free cheeks separable on the line of the facial sutures from the cranidium. In the Mesonacidæ the facial sutures are in a state of symphysis and the free cheeks and cranidium are frequently not to be distinguished.

STRATIGRAPHIC POSITION OF THE GENERA AND SPECIES

All of the known species of the Mesonacidæ occur in the Lower Cambrian or Georgian terrane. At the type locality in the town of Georgia, Vermont, *Olenellus* and *Mesonacis* occur in the same beds, and as far as known to me all known species of *Olenellus,* as restricted, are from the upper zones of the Georgian terrane.

In the accompanying table of genera and species the Lower Cambrian is arbitrarily divided into four divisions or zones, as follows:

D=Olenellus, or upper zone.
C=Callavia zone.
B=Elliptocephala zone.
A=Nevadia, or lower zone.

In the *Nevadia* zone (A) we find the genus *Nevadia* [pl. 23] with one species, also a species that is referred to *Holmia, H. rowei* [pl. 29].

In zone "B" which is above zone "A" *Elliptocephala* occurs, also, doubtfully, *Wanneria* and *Olenellus.*

In zone "C" which is high up in the Lower Cambrian, but not the upper zone, *Callavia* is represented by five species, *Mesonacis* by two, *Holmia* by two, *Olenellus* by one, and two are doubtfully referred to this horizon.

In zone "D" *Olenellus* is represented by eleven species, *Pædeumias* by one, *Wanneria* by two, *Callavia* by one, and *Mesonacis* by one.

Genera and Species.	Lower Cambrian.			
	A[1]	B[1]	C[1]	D[1]
Nevadia, new genus	T			
weeksi, new species	x			
Elliptocephala Emmons	......	T		
asaphoides Emmons	......	x		
Mesonacis Walcott	......	......	x	T
? mickwitzi (Schmidt)	......	......	x ?	
Mesonacis torelli (Moberg)	......	......	x	
vermontana (Hall)	......	......	......	x
Holmia Matthew	x	......	T	
kjerulfi (Linnarsson)	......	......	x	
lundgreni (Moberg)	......	......	x	
rowei, new species	x			
Callavia Matthew	......	......	T	x
bröggeri (Walcott)	......	......	x	
burri, new species	......	......	x	
callavei (Lapworth)	......	......	x	
cartlandi (Raw) (MSS.)	......	......	x	
crosbyi, new species	......	......	x	
nevadensis, new species	......	......	......	x
Wanneria, new genus	......	x ?	......	T
gracile, new species	......	x ?	......	
halli, new species	......	......	......	x
walcottanus (Wanner)	......	......	......	x
Pædeumias, new genus	......	......	......	x
transitans, new species	......	......	......	x
Olenellus Hall	......	x ?	x	T
argentus, new species	......	x ?	......	
canadensis, new species	......	......	......	x
claytoni, new species	......	x ?	......	
fremonti, new species	......	......	x	
gigas Peach	......	......	......	x
gilberti Meek	......	......	......	x
gilberti var. undt.	......	......	......	x
lapworthi (Peach)	......	......	......	x
logani, new species	......	......	......	x
reticulatus Peach	......	......	......	x
thompsoni Hall	......	......	......	x
thompsoni crassimarginatus, new variety	......	......	......	x
? walcotti (Shaler and Foerste)	......	......	x ?	
? sp. undt. (Sweden)	......	......	x ?	
? sp. undt. (Scotland)	......	......	......	x
Peachella, new genus	......	......	......	x
iddingsi (Walcott)	......	......	......	x
Olenelloides Peach	......	......	......	x
armatus Peach	......	......	......	x

[1] See page 250, opposite, for the explanation of these symbols.

ABRUPT APPEARANCE OF THE MESONACIDÆ

I will not discuss at length the question of the abrupt appearance of the Mesonacidæ fauna [1] in this paper as it will be the subject of a paper on the Abrupt Appearance of the Cambrian Fauna of North America,[2] to be read before the International Geological Congress at Stockholm in August, 1910.

I have been gradually coming to the conclusion that the most natural explanation of the absence of the traces of a distinct pre-Cambrian fauna is that the North American continent in pre-Cambrian time was at such an elevation above the sea that there is now no record of the sediments deposited about the continental area at that time. This presupposes that the great series of pre-Cambrian Algonkian sediments in the Rocky Mountain region were deposited in an inland mediterranean, or a series of great lakes and flood plains such as existed in Tertiary times.[3] The same applies to the Lake Superior, Texas, Arizona, and all of the later pre-Cambrian Algonkian formations.

On this hypothesis the evolution of the pre-Cambrian fauna was taking place in waters contiguous to the continental area, and their remains, buried in the sediments then accumulating, have not been found, owing to the fact that those sediments are now probably off the coast lines of the continent buried beneath the sea. That such a condition existed is suggested by the almost total absence of any traces of life in the pre-Cambrian sediments now existing on the continent.

GEOGRAPHIC DISTRIBUTION

Olenellus, as now restricted, has been found on both the western and eastern sides of North America and the northwest of Scotland. *Olenellus canadensis, O. gilberti,* and *O. fremonti* occur in the northern section of the Cordilleran Province in Alberta and British Columbia, and the two latter extend far to the south in Nevada and California. In the Appalachian Province *O. thompsoni*

[1] This name will be used by me in the future as the genus *Olenellus* is now limited to the upper zone of my Olenellus Fauna of 1891 [Walcott, 1891, pp. 515-597].

[2] This will be published as No. 1 of Vol. 57 of the Smithsonian Miscellaneous Collections.

[3] The crustacean and annelid fossils described [Walcott, 1899, p. 238] might quite as well have been fresh water as marine forms. There is nothing as far as known to indicate that they were necessarily limited to a marine habitat.

and the closely related *Pœdeumias transitans* range from Alabama to Lake Champlain and down the St. Lawrence valley to the southeastern end of Labrador in the Atlantic Province. On the eastern side of the Atlantic *Olenellus lapworthi* is abundant in northwest Scotland on Loch Maree.

Olenellus has a wide distribution, and it may in the future be found in Siberia and far to the north within the Arctic Circle on both North America and Asia and adjacent islands.

Holmia has both an extended geographic and stratigraphic range, especially if we consider with it the closely related *Callavia* and *Wanneria*. *Holmia rowei* in the lower portion of the known Lower Cambrian horizon of Nevada is unknown elsewhere, and *H. kjerulfi* is limited to the Scandinavian area, but probably will be found to extend eastward into Russia and possibly Siberia. *Callavia* is essentially an Atlantic Province genus as the one species from Nevada, *C. ? nevadensis,* is a more or less doubtful reference.

Elliptocephala and *Nevadia* are each limited to a single species and a narrow distribution and stratigraphic range. *Mesonacis vermontana* occurs in western Vermont on Lake Champlain, and it will probably be found in the St. Lawrence River area. *Mesonacis ? mickwitzi* is probably a *Mesonacis,* but this awaits further proof.

Nothing is known of the Mesonacidæ on the Asiatic continent, and the evidence for the presence of any of its forms in Australia or elsewhere than as described in this paper is not sufficiently conclusive to justify my accepting it. I am prepared to learn that undoubted specimens have been found in Siberia and Australia, and possibly Sardinia and to the north in Spain and France.

With our present information, the Mesonacidæ is confined to western Europe and North America. The immediate descendants of the family are probably *Paradoxides* about the Atlantic Basin, and *Redlichia* [Walcott, 1905, p. 25] in eastern Asia, northern India, and Australia.

TRANSITION FROM THE MESONACIDÆ TO THE PARADOXINÆ

The question of the transition from the Lower Cambrian fauna to the Middle Cambrian fauna is one that has not been fully worked out. That all of the genera of the Mesonacidæ should disappear before the undoubted appearance of *Paradoxides* is a very significant fact and to me indicates that there was a transition fauna in the Atlantic Province, and that in most instances owing to shifting shore

lines and irregular deposition of sediments the record is incomplete. Both in England [Cobbold, 1910, pp. 19, 42, and 47] and New Brunswick [Walcott, 1900, pp. 302 and 320-322] the *Protolenus* fauna [Matthew, 1895, pp. 101-153] has been found beneath the horizon of the *Paradoxides* fauna and above the horizon of the Lower Cambrian fauna. The *Protolenus* fauna has a commingling of generic types common to both the Lower and Middle Cambrian faunas, but as yet nothing has been found that could be construed to be a connecting link between the Mesonacidæ and Paradoxinæ. In the western Pacific Province fauna of China, India, and Australia the genus *Redlichia* [Walcott, 1905, pp. 24-25] appears to be a form that combines characteristics of both families, and it may be that *Albertella* [Walcott, 1908*a*, pls. 1 and 2] may be found to have retained some of the characters of the Mesonacidæ; also *Zacanthoides* [Walcott, 1908*a*, pl. 3]. The genus *Albertella* occurs in the passage beds between the Lower and Middle Cambrian or in beds at the top of the Lower Cambrian above *Olenellus canadensis.*

A specimen of the cephalon of *Paradoxides* was found by Mr. George Edson [1907, p. 209], of St. Albans, Vermont, in the St. Albans shales just west of the City of St. Albans. The St. Albans shales are argillaceo-arenaceous and carry lentiles of limestone that are more or less fossiliferous. The *Paradoxides* occurs in the shale and in a limestone lentile. Fig. 10 is taken from a compressed cephalon in the shale, and fig. 11 from a cephalon occurring in the limestone lentile along with *Agraulos.* As far as can be determined from the specimens of the cephalon the species is identical with *Paradoxides harlani* Green from the Braintree quarries near Boston, Massachusetts.

Mr. H. W. Shimer[1] identified under the name "*Olenellus* (*Holmia*) *bröggeri* (Shimer)" a crushed cephalon found in association with *Paradoxides harlani* Green. Through the courtesy of Dr. T. A. Jaggar, of the Massachusetts Institute of Technology at Boston, I have been able to study and photograph the specimen identified by Mr. Shimer and it is here reproduced as fig. 12. Beside it [fig. 13] is an undoubted cephalon of *P. harlani* from the same quarry. The Shimer specimen is compressed laterally so as to narrow the glabella and crowd the palpebral lobe inward and out of shape. I find among specimens of the cephalon of *P. harlani* considerable variation in the length of the palpebral lobe. In some it continues up to the side

[1] American Journ. Sci., 4th ser., Vol. 24, 1907, p. 177.

of the anterior lobe of the glabella and in others there is scarcely a trace of the ridges connecting the lobe above the eye, and the anterior glabellar lobe. There is no special reason why *Holmia* should not have continued on into *Paradoxides* time, but I do not think it is proven to have done so by the specimen described by Mr. Shimer.

FIG. 10.

FIG. 11.

FIG. 12.

FIG. 13.

FIG. 10. Cephalon of *Paradoxides* compressed in the St. Albans shale just west of the city of St. Albans, Franklin County, Vermont. U. S. National Museum.

11. Cephalon of *Paradoxides* from lentile of limestone in the St. Albans shale, at the same locality as fig. 10. U. S. National Museum.

12. Specimen identified by H. W. Shimer [1907, p. 177] as "*Olenellus* (*Holmia*) *bröggeri*." It should be compared with fig. 13.

13. Cephalon of *Paradoxides harlani* Green from the Middle Cambrian at Braintree, Massachusetts. U. S. National Museum.

DESCRIPTION OF GENERA AND SPECIES

NEVADIA, new genus

Dorsal shield broad, ovate. Cephalon large, semicircular in outline, about one-third the length of the dorsal shield; genal angles extended into spines; facial sutures rudimentary or in a condition of symphysis; eyes crescentic, with ridges uniting them with the anterior lobe of the glabella; glabella elongate, with a relatively small anterior lobe and three posterior transverse lobes; strong occipital ring.

Thorax with twenty-eight segments; body of pleuræ nearly straight; pleural furrow broad and parallel to the transverse axis of the pleuræ; pleuræ terminating in long, curved spines that are much shorter on the posterior eleven segments in the type species which are without a distinct, furrowed pleural lobe.

Pygidium small, without pleural lobes and transverse furrows.

Surface minutely granular and with irregular network of fine, irregular, anastomosing ridges.

Genotype.—Nevadia weeksi, new species.

The generic name is given after the State of Nevada, in which the specimens were found.

Stratigraphic range.—Lower Cambrian: Silver Peak group where the type species ranges through a band of arenaceous shale and quartzitic sandstone 222 feet in thickness. In the Barrel Spring section [Walcott, 1908, p. 189, 12 of section] the species was placed under the genus *Holmia.*

Geographic distribution.—Sixteen miles south and 10 miles northwest of Silver Peak, Esmeralda County, southwestern Nevada.

Observations.—*Nevadia* is probably the most primitive form of the Mesonacidæ. The strong ridge uniting the eye lobe and the frontal lobe of the glabella in the adult is a marked feature of the young of *Elliptocephala asaphoides* [pl. 24, figs. 3, 6, 7; pl. 25, figs. 9, 10, 11]; *Olenellus fremonti* [pl. 37, figs. 9, 10, 11]; and, as a case of reversion, in *Olenellus thompsoni* [pls. 34, 35] and similar forms of *Olenellus* from the upper portion of the Lower Cambrian terrane.

Nevadia appears to be the more primitive type and it occurs much deeper down in the Cambrian section than *Mesonacis vermontana* and *Elliptocephala asaphoides.*

The elongate thorax of many segments; spinose extensions of the pleuræ; narrowing of the pleural lobes and their absence on the ten posterior segments; and the very small, simple pygidium without

pleural lobes are all primitive characters indicating a nearer approach to an annelidian ancestor than any other form of the Mesonacidæ.

Nevadia differs from *Elliptocephala* Emmons [pl. 24] in the more primitive character of the eye lobe in the adult and in the character of the posterior rudimentary segments.

Nevadia differs from *Mesonacis* Walcott [pl. 26] in the absence of an enlarged third thoracic segment in the adult and in the character of the ten posterior rudimentary thoracic segments.

NEVADIA WEEKSI, new species

PLATE 23, FIGS. 1-7, TEXT FIGS. 14 AND 15

Holmia weeksi WALCOTT, 1908, Smithsonian Misc. Coll., Vol. 53, No. 5, p. 189. (Name given in list of fossils occurring in 12 of the section; the species does not occur in 3, 6, or 11 of the same section, nor in 2j of the Waucoba section [p. 187]. The specimens identified with this species from 3 of the section are referred in this paper to *Wanneria gracile;* those from 6 are referred to *Olenellus fremonti;* those from 11 are not specifically identified; and those from 2j of the Waucoba section are referred to *Olenellus fremonti.*)

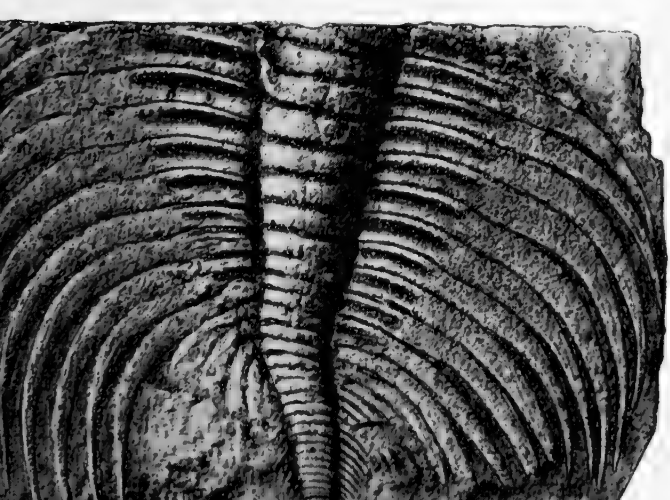


FIG. 14.

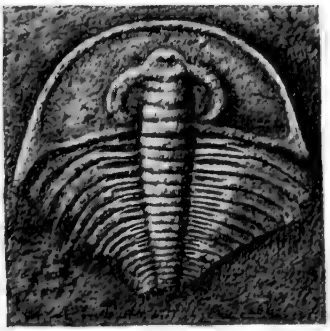


FIG. 15.

Nevadia weeksi, new species.

FIG. 14. Posterior portion of the dorsal shield preserving 18 rudimentary segments and the pygidium. Locality No. 1f, south of Silver Peak, Esmeralda County, Nevada. U. S. National Museum, Catalogue No. 56792i.

15. Anterior portion of dorsal shield associated with the specimen represented by fig. 14. U. S. National Museum, Catalogue No. 56792j.

Dorsal shield large; gently convex as preserved in the arenaceous shales; broadly ovate in outline. Cephalon transversely semicircular in outline, one-third the length of the adult dorsal shield; bordered by a narrow, wire-like rim that is extended at the genal angles into a slender spine; intergenal angles distinctly shown in adult specimens [fig. 3, pl. 23]. Glabella about four-fifths of the length of the cephalon; it narrows from the occipital segment towards the frontal lobe, as shown by figs. 2 and 3; in a small specimen of the cephalon 3.75 mm. in length it is almost cylindrical, with the sides converging slightly toward the front; the anterior lobe is about two-fifths the length of the glabella and narrower than the lobes posterior to it; it was evidently convex before being flattened in the shale, and narrowed toward the front; the three posterior transverse lobes decrease in size from the front to the posterior lobe, and slope from each side gently backwards toward the center; the glabellar furrows are narrow and in the specimens available for study are united at the center by a shallow groove. Occipital segment transverse, stronger than the posterior segment of the glabella and separated from it by a narrow, clearly defined furrow.

Eye lobe long, crescentiform, broad at the base and extending from opposite the back portion of the anterior lobe of the glabella back to nearly opposite the occipital furrow; it is united, even in large adult specimens, by a strong ridge to the frontal lobe of the glabella [fig. 3], very much in the same manner as in small cephalons of *Elliptocephala asaphoides* [pl. 24, figs. 3, 4, 6, and 7]; the posterior end of the eye lobe is rather close to the dorsal furrow between it and the glabella. Cheeks broad, large, and beautifully marked on the interior surface by a system of irregular canals extending from the base of the eye lobe toward the outer margin [fig. 6].

Thorax elongate, tapering gently from the cephalon to the pygidium. It has twenty-eight segments, the anterior seventeen of which are progressively smaller, but otherwise uniform in character; these may be designated as the normal segments of this species; the posterior eleven segments have only the curved spinose extension of the segment beyond the axial lobe, the body portion of the pleural lobe not appearing back of the seventeenth segment. In a small dorsal shield with a cephalon 3.75 mm. in length the pleural lobes disappear beside the axial lobe at about the tenth segment from the cephalon. Unfortunately, the posterior segments are broken off. The axial lobe is convex; less than one-half the width of the pleural

lobes with their spinose extensions. On large specimens an elongate node occurs at the posterior center of each segment; it is not known if the posterior eleven segments had median spines of the type occurring on *Elliptocephala asaphoides* [pl. 24, fig. 1]. The pleural lobes of the anterior seventeen segments gradually become shorter until at the seventeenth there is only a trace of the lobe and its median furrow; each pleura has a broad, strong furrow that is nearly the full width of the segment at its union with the axial lobe, from whence it narrows gradually to the base of the spinose extension of the pleura; the latter are elongate and gently curved backward near the cephalon; from whence they increase in length and curvature to the seventeenth segment, where their length and backward curvature are so great that they extend a considerable distance back of the posterior eleven segments and pygidium; the posterior eleven segments of the axial lobe have a backward extending lateral spine attached directly to them [pl. 23, fig. 4] without any intervening grooved pleural lobe.

Pygidium apparently a continuation of the axial lobe without pleural lobes or spines; it is small and, as far as can be determined from compressed specimens, it is a simple plate of about equal length and breadth that narrows toward the posterior margin.

Surface minutely granular and with very narrow raised lines or ridges that unite to form an irregular network over glabella and the central portions of the thoracic segments. On the broad cheeks the ridges radiate more or less irregularly from the base of the eye toward the margins of the cephalon.

Dimensions.—A dorsal shield 41 mm. in length that is flattened in arenaceous shale has the following dimensions. (Two thoracic segments are crowded up beneath the cephalon):

	mm.
Cephalon:	
Length	13.25
Width at base	31.5
Length of eye lobe	5.
Length of glabella	9.
Width of glabella at base	7.
Width of glabella at front	4.
Thorax:	
Length	26.
Width at anterior segment, including spinose extension of the pleuræ	33.
Width at seventeenth segment, including spinose extension	30.
Width at twenty-eighth segment, including spinose extension	24.

Width of axial lobe, anterior segment	6.5
Width of axial lobe, seventeenth segment	3.
Width of axial lobe, twenty-seventh segment	1.5
Width of pleural lobe, anterior segments	6.5
Width of pleural lobe, seventeenth segment	1.
Pygidium:	
Length ... about	1.75
Width at front	1.5

The preceding description is based on specimens compressed in an arenaceous shale that has had sufficient distortion to flatten the dorsal shield and widen it. The normal form of the cephalon is probably nearest to that of the cephalon represented by fig. 5. The largest dorsal shield found indicates a total length of 126 mm.

Observations.—This species is one of the most primitive known to me. The form of the anterior lobe of the glabella is primitive, and its twenty-eight segments with posterior eleven so very simple indicate a closer approach to annelidian progenitors than any of its associates in the Lower Cambrian, Georgian, fauna; it has three more thoracic segments than *Mesonacis vermontana* (Hall) [pl. 26, fig. 1] and the posterior eleven are more primitive in form.

Nevadia weeksi differs from *Elliptocephala asaphoides* [pl. 24] in so many ways that it is not necessary to describe them. The points of generic similarity are in the cephalon where the general characters are similar; in the thorax where the segments are of the same type back to the rudimentary segments; and the pygidium appears to be similar, although relatively much smaller in *N. weeksi.*

This species was identified and named *Holmia weeksi,* new species, and the name used in the Barrel Spring geological section [Walcott, 1908, pp. 188-189], and in the Waucoba Springs section [*Idem,* pp. 186-187].

The specific name is in recognition of the excellent work of Mr. F. B. Weeks, formerly of the United States Geological Survey.

FORMATION AND LOCALITY.[1]—Lower Cambrian: Silver Peak Group in hard arenaceous shales at the following localities: (**1f**) *in No. 12 of the Barrel Spring section* [*Walcott, 1908c, p. 189*], *3 miles (4.8 km.) northeast of Barrel Spring, which is 10 miles (16 km.) south of the town of Silver Peak;* and (**174b**) 10 miles (16 km.) northwest of Silver Peak on ridge north of Red Mountain; both in Esmeralda County, Nevada.

[1] The type locality is given in italics, when there is more than one locality. The locality numbers in heavy-face type are the numbers assigned to the specimens in the collections of the United States National Museum.

Genus MESONACIS Walcott

Barrandia HALL (in part), 1860, Thirteenth Ann. Rept. New York State Cab. Nat. Hist., p. 115. (Described and discussed. As described the genus includes forms now referred to both *Mesonacis* and *Olenellus.* Beginning with the 5th paragraph the text is a description of "Barrandia thompsoni.")

Barrandia HALL (in part), 1861, Report on the Geology of Vermont, Vol. 1, p. 369. (Copy of Hall, 1860, p. 115; the reference includes species referred to both *Mesonacis* and *Olenellus.* Beginning with the 5th paragraph the text is a description of the species "*Barrandia thompsoni*"; this is also copied from the preceding reference.)

Olenellus FORD (in part), 1881, American Journ. Sci., 3d ser., Vol. 22, p. 251. (As discussed in this paper the genus *Olenellus* includes forms now referred to *Elliptocephala, Mesonacis,* and *Olenellus.*)

Mesonacis WALCOTT, 1885, American Journ. Sci., 3d ser., Vol. 29, pp. 328-330. (Discussed as a new genus.)

Mesonacis WALCOTT, 1886, Bull. U. S. Geol. Survey, No. 30, p. 158. (Merely gives its position in the classification of the trilobites.)

Olenellus HOLM (in part), 1887, Geol. Fören. i Stockholm Förhandl., Bd. 9, Häfte 7, pp. 498-499. (Described in Swedish. As described and discussed throughout the paper, the genus includes many of the forms now placed in the family Mesonacidae.)

Elliptocephalus (*Schmidtia*) MARCOU (in part), 1890, American Geologist, Vol. 5, p. 363. (*Schmidtia* is proposed as a new subgenus to include forms that are now referred to *Mesonacis mickwitzi, Mesonacis vermontana,* and *Zacanthoides typicalis.*)

Not *Schmidtia* VOLBORTH [1860] = Brachiopod.

Not *Schmidtia* BALS-CRIV. = Protozoan.

Olenellus (*Mesonacis*) WALCOTT, 1891, Tenth Ann. Rept. U. S. Geol. Survey, p. 637. (*Mesonacis* is here placed as a subgenus of *Olenellus.* The forms referred to the subgenus are now placed under both *Mesonacis* and *Elliptocephala.*

Mesonacis COLE, 1892, Natural Science, Vol. 1, pp. 342 and 344. (Discussed. In the legend of figure 2, p. 343, *Mesonacis* is placed as a subgenus of *Olenellus.*)

Mesonacis PEACH and HORNE (in part), 1892, Quart. Journ. Geol. Soc. London, Vol. 48, p. 236. (As defined this genus includes forms now referred to both *Elliptocephala* and *Mesonacis.*)

Mesonacis (*Olenellus*) PEACH, 1894, Idem, Vol. 50, pp. 671-674. (As discussed in these pages this genus includes forms now referred to both *Elliptocephala* and *Mesonacis.*)

Elliptocephala (*Mesonacis*) BEECHER, 1897, American Journ. Sci., 4th ser., Vol. 3, p. 192. (*Mesonacis* is stated to be probably of only subgeneric value under *Elliptocephala.*)

Mesonacis MOBERG, 1899, Geol. Fören. i Stockholm Förhandl., Bd. 21, Häfte 4, p. 318. (Described in Swedish. The genus is discussed frequently on pages 309-320 of the paper.)

Schmidtia MOBERG, 1899, Idem, p. 319 and footnote. (Discussed in Swedish.)

Mesonacis WELLER, 1900, Ann. Rept. Geol. Survey, New Jersey, for 1899, pp. 50-51. (Discussed.)

Schmidtiellus MOBERG, in Moberg and Segerberg, 1906, Meddelande från Lunds Geologiska Fältklubb, Ser. B, No. 2 (Aftryck ur Kongl. Fysiografiska Sällskapets Handlingar, N. F., Bd. 17), p. 35, footnote. (Proposed as a new genus by Moberg for *Schmidtia* Marcou, preoccupied.)

Type of the genus *Mesonacis vermontana* Hall. The description of the genus is incorporated with that of the type species [Walcott, 1886, pp. 158-162], and its relations are discussed in this paper under observations on the Mesonacidæ (pp. 244, 246, and 250).

MESONACIS MICKWITZI (Schmidt)

PLATE 26, FIG. 4, TEXT FIGS. 16 AND 17.

Olenellus mickwitzi SCHMIDT, 1888, Mém. Acad. Imp. Sci. St.-Pétersbourg, 7th ser., Vol. 36, No. 2, pp. 13-19, pl. 1, figs. 1-25. (Described and discussed. Figure 1, with the exception of the cephalon which was added from other specimens, is copied in his paper, pl. 26, fig. 4.)

Olenellus mickwitzi SCHMIDT, 1889, Mélanges Géol. et Paléontol. tirés du Bull. Acad. Imp. Sci. St.-Pétersbourg, N. S., Vol. 1 (33), pp. 191-195, 10 text figures on page 193. (Described and discussed, giving additional details. Figures 1 and 9 are copied in this paper as text figures 16 and 17, p. 263.)

Elliptocephalus (*Schmidtia*) *mickwitzi* (Schmidt), MARCOU, 1890, American Geologist, Vol. 5, p. 363. (The subgenus *Schmidtia* is proposed for this and other species.)

Olenellus (*Mesonacis*) *mickwitzi* (Schmidt), WALCOTT, 1891, Tenth Ann. Rept. U. S. Geol. Survey, p. 634, pl. 93, fig. 1. (Merely refers the species to *Mesonacis* and copies Schmidt's restoration [1888, pl. 1, fig. 1].)

Mesonacis mickwitziæ PEACH, 1894, Quart. Journ. Geol. Soc. London, Vol. 50, p. 672, text fig. B, p. 673. (Mentioned. The text figure is copied from a part of one of Schmidt's figures.)

Olenellus (*Mesonacis*) *mickwitzi* FRECH, 1897, Additional plates inserted in 1897 in Lethæa geognostica, Pt. 1, Lethæa palæozoica, Atlas, pl. 1a, fig. 8. (Figure 8 is copied from Schmidt, 1888, pl. 1, fig. 1.)

Schmidtia mickwitzi (Schmidt), MOBERG, 1899, Geol. Fören. i Stockholm Förhandl., Bd. 21, Häfte 4, pp. 319-320, pl. 13, figs. Va-c. (Described and discussed; figure Va is copied from Schmidt [1888, pl. 1, fig. 1] and figures Vb and Vc are copied from Schmidt [1889, figs. 1 and 9, p. 193].)

Schmidtiellus mickwitzi MOBERG, in Moberg and Segerberg, 1906, Meddelande från Lunds Geologiska Fältklubb, Ser. B, No. 2 (Aftryck ur Kongl. Fysiografiska Sällskapets Handlingar, N. F., Bd. 17), p. 35, footnote. (Merely proposes the new generic name *Schmidtiellus* for this species, *Schmidtia* Marcou being preoccupied.)

FIG. 16.

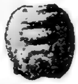


FIG. 17.

Mesonacis mickwitzi (Schmidt).
FIG. 16. Cephalon, copied from Schmidt, 1889, fig. 1, p. 193.
17. Pygidium, copied from Schmidt, 1889, fig. 9, p. 193.

This species is known only by fragments that have been most fully described and illustrated by Schmidt [1888 and 1889]. Dr. Schmidt's restoration of the posterior portions of the thorax is copied on pl. 26, fig. 4. The similarity to *Mesonacis vermontana* is shown by figs. 1 and 2, pl. 26. Schmidt [1889] says that the pygidium shows a slight notch on the back edge. He also observed traces of transverse furrows on the axis and very faintly on the lateral lobes. The fragments of the hypostoma indicate that the general form is similar to that of *Olenellus*.

The cephalon of *M. mickwitzi* is much like that of *M. vermontana*, and the pygidium, posterior thoracic segments, and the great spine on the sixth (?) segment from the pygidium are also of the same type. Dr. Moberg [1899, footnote, p. 319] thinks that as the generic name *Schmidtia* is already in existence, and that as the type species is so imperfectly known it would be well to retain *Schmidtia* for it, and not refer it to *Mesonacis*. These reasons do not appeal strongly to me, and as *Schmidtia* was preoccupied by Volborth in 1860, I think it is best to refer the species to *Mesonacis* and retain it there until further information of it is obtained. Dr. Moberg [1906] proposed *Schmidtiellus* to take the place of *Schmidtia*, but, as stated above, I think it best to retain the species under *Mesonacis* until more is known of it.

FORMATION AND LOCALITY.—Lower Cambrian: The following localities are given by Schmidt, 1888, p. 19: (1) lower layers of the Fucoid sandstone[1] on Jaggowal Brook; (2) at the same horizon near the cement works on Kunda Brook; and (3) glauconitic sandstone at the base of the section in Streitberg; all near Reval, Government of Esthonia, Russia.

[1] Esthonia formation of Marcou [1890, pp. 360-361].

MESONACIS TORELLI (Moberg)

Plate 26, Figs. 5-18

Olenellus torelli Moberg, 1892, Om Olenellusledet i sydliga Skandinavien, p. 3. (Specimens exhibited at 14th meeting of Scandinavian naturalists at Copenhagen discussed.)

Schmidtia ? torelli Moberg, 1899, Geol. Fören. i Stockholm Förhandl., Bd. 21, Häfte 4, pp. 330-338, pl. 15, figs. 1-17. (Described and discussed in Swedish. Figures 1b, 4, 6, 7, 8, 10, 12, 15, and 16 of Moberg are copied in this paper, pl. 26, figs. 5a, 7, 9, 17, 16, 18, 14, 11, and 15 respectively. Plaster casts of the specimens represented by figures 1a, 6, and 14 of Moberg are figured in this paper, pl. 26, figs. 5, 10, and 10a, and 8 respectively.)

Dr. Joh. Chr. Moberg gives a very full description of this interesting species as represented by numerous fragments of the cephalon and thorax and entire specimens of the pygidium. Dr. Moberg very kindly sent me casts of the specimens he used for illustration, also a few natural specimens. From the casts and specimens a few figures have been made that will serve to indicate the principal characters of the species.

The generic reference is based on the general similarity of the cephalon and pygidium to that of *Mesonacis vermontana* [pl. 26, fig. 1], the presence of a thoracic segment bearing a large spine, and the fact so well stated by Dr. Moberg that the central lobe of the thorax was about as wide as half the width of the thorax, this indicates a slender thorax similar to that of *M. vermontana.*

Obolella lindströmi Walcott, *O. mobergi* Walcott, and a *Hyolithes* like *H. degeeri* Holm occur with fragments of *M. torrelli.*

Formation and Locality.—Lower Cambrian: (**312v**) *bluish-gray sandstone, along the coast near Björkelunda, south from Simrishamn, Province of Kristianstad, Sweden* [Moberg, 1899, p. 337].

The species is doubtfully identified by Moberg [1899, p. 337] in sandstone occurring between Sularp and Norrtorp, near Fogelsång, Province of Malmöhus, Sweden.

MESONACIS VERMONTANA (Hall)

Plate 26, Figs. 1-3

Olenus vermontana Hall, 1859, Twelfth Ann. Rept. New York State Cab. Nat. Hist., pp. 60-61, fig. 2, p. 60. (Described and discussed as a new species.)

Olenus vermontana Hall, 1859, Nat. Hist. New York, Paleontology, Vol. 3, pt. 1, p. 527, text figure. (Copy of the preceding reference.)

Barrandia vermontana HALL, 1860. Thirteenth Ann. Rept. New York State Cab. Nat. Hist., p. 117, text figure. (Discussed. The figure is copied from Hall, 1859, fig. 2, p. 60.)

Paradoxides vermonti EMMONS, 1860, Manual of Geology, 2d ed., p. 280, note A. (Note on the stratigraphic position of the species.)

Paradoxides vermontana BARRANDE, 1861, Bull. Soc. Géol. de France, 2d ser., Vol. 18, pp. 277-278, pl. 5, fig. 8. (Translates into French the description given by Hall [1859, pp. 60-61] and copies Hall's outline figure [1859, fig. 2, p. 60].)

? *Paradoxides vermontana* (Hall), BILLINGS, 1861, Geol. Survey Canada, Paleozoic Fossils, p. 11. (Mentions presence of heads representing this species at Anse au Loup. In view of the close similarity between the heads of several of the forms now referred to the different genera of the Mesonacidæ the occurrence of this species at the locality mentioned must be regarded as doubtful.)

Barrandia vermontana HALL (in part), 1861, Report on the Geology of Vermont, Vol. 1, p. 370, first 6 paragraphs. (Copies the paragraph given by Hall [1860, p. 117] and describes the species. The text includes reference to figures given by Hall [1862, pl. 13] which are referred in this paper to *Paedeumias transitans.*)

Barrandia vermontana HALL (in part), 1862, Report on the Geology of Vermont, Vol. 2, pl. 13, fig. 2 (not figs. 4 and 5, referred in this paper to *Paedeumias transitans*). (Figure 2 is copied from Hall, 1860, text figure, p. 117; figures 4 and 5 appear to represent forms more like *Paedeumias transitans* than *Mesonacis vermontana*).

Olenellus vermontana HALL, 1862, Fifteenth Ann. Rept. New York State Cab. Nat. Hist., p. 114. (Generic name *Olenellus* proposed.)

Olenellus vermontana BILLINGS, 1865, Geol. Survey Canada, Paleozoic Fossils, Vol. 1, p. 11. (Reprinted from Billings, 1861a, p. 11, substituting *Olenellus* for *Paradoxides.*)

Olenellus vermontanus FORD, 1881, American Journ. Sci., 3d ser., Vol. 22, fig. 13, p. 258. (Figure 13 is copied from Hall, 1859, fig. 2, p. 60.)

Not *Olenellus vermontana* WHITFIELD, 1884, Bull. American Mus. Nat. Hist., Vol. 1, No. 5, pp. 152-153, pl. 15, figs. 2-4. (Referred in this paper to *Paedeumias transitans.*)

Mesonacis vermontana WALCOTT, 1885, American Journ. Sci., 3d ser., Vol. 29, pp. 328-330, figs. 1 and 2, p. 329. (Discussed. Figures 1 and 2 are outline drawings of the specimen figured in this paper, pl. 26, figs. 1 and 2.)

Mesonacis vermontana (Hall), WALCOTT, 1886, Bull. U. S. Geol. Survey, No. 30, pp. 158-162, pl. 24, figs. 1, 1a-b. (Copies the original description given by Hall, 1859, pp. 60-61, and describes and discusses the species. Figure 1 is copied from Hall, 1859, fig. 2, p. 60; and figures 1a and 1b are drawn from the specimen figured by Walcott, 1885, text figs. 1 and 2, p. 329. This specimen is the one illustrated in this paper, pl. 26, figs. 1 and 2.)

Olenellus vermontana (Hall), HOLM, 1887, Geol. Fören. i Stockholm Förhandl., Bd. 9, Häfte 7, pp. 515-516. (Described in Swedish. The species is frequently mentioned also in the discussion of "*Olenellus kjerulfi*.")

Elliptocephalus (*Schmidtia*) *vermontana* MARCOU, 1890, American Geologist, Vol. 5, p. 363. (The subgenus *Schmidtia* is proposed for this and other species.)

Olenellus (*Mesonacis*) *vermontana* (Hall), WALCOTT, 1891, Tenth Ann. Rept. U. S. Geol. Survey, p. 637, pl. 87, figs. 1, 1a-b. (No text reference. Figure 1 is copied from Hall, 1859, fig. 2, p. 60; and figures 1a and 1b are copied from Walcott, 1886, pl. 24, figs. 1a and 1b.)

Olenellus (*Mesonacis*) *vermontana* (Hall), COLE, 1892, Natural Science, Vol. 1, pp. 340 and 341, fig. 2, p. 343. (Discussed. The figure is an outline drawing of the figure given by Walcott, 1886, pl. 24, fig. 1a.)

Mesonacis vermontana MOBERG, 1899, Geol. Fören. i Stockholm Förhandl., Bd. 21, Häfte 4, p. 318, pl. 13, fig. 4. (Mentioned at several places in the text. The figure is copied from Walcott, 1886, pl. 24, fig. 1a.)

A detailed description of this species was given in 1886 [Walcott, 1886, p. 158]. Nothing has been added to our information of it since that date and no additional specimens have been discovered. The finding of a specimen of *Pædeumias transitans* in association with *Mesonacis vermontana* at Georgia, Vermont, in which three rudimentary segments and a Mesonacis-like pygidium occur beneath the telson [pl. 33, fig. 1] corroborated the view held in 1886 [Walcott, 1886, p. 166] that the body of *Mesonacis* was shortened by the absorption of the posterior segments and the spine on the fifteenth segment became the elongate telson of *Olenellus*. At first I was inclined to refer the form with the three rudimentary segments to *Mesonacis*, but with the discovery at York, Pennsylvania, by Prof. Atreus Wanner, of numerous specimens with from two to six rudimentary segments, and that all the rudimentary segments were unlike those of *Mesonacis vermontana*, I decided finally to include such specimens in a new genus *Pædeumias*, and to retain in *Mesonacis* only those specimens that have only normal thoracic segments posterior to the fifteenth spine-bearing segment.

FORMATION AND LOCALITY.—Lower Cambrian: (25) *siliceous shale just above Parkers quarry, near Georgia, Franklin County, Vermont.*

Specimens corresponding to the cephalon of this species occur at Bonne Bay, Newfoundland, and L'Anse au Loup, on the north side of the straits of Belle Isle, Labrador.

Genus ELLIPTOCEPHALA Emmons

Elliptocephala EMMONS, 1844, Taconic System, p. 21, legend of fig. 1. (Characterized.)

Elliptocephala EMMONS, 1846, Nat. Hist. New York, Agriculture, Vol. 1, pt. 5, p. 65, legend of fig. 1. (Copy of preceding reference.)

Olenus HALL, 1847, Nat. Hist. New York, Paleontolgy, Vol. 1, p. 256, footnote. (Places "*Elliptocephalus*" as a synonym of *Olenus.*)

Eliptocephalus EMMONS, 1849, Proc. American Assoc. Adv. Sci., First meeting, p. 18. (Notes on the genus as distinct from *Olenus* and *Paradoxides.*)

Eliptocephalus EMMONS, 1855, American Geology, Vol. 1, pt. 2, pp. 114-115. (Discussed.)

Eliptocephalus (Emmons), MARCOU, 1860, Proc. Boston Soc. Nat. Hist., p. 371. (Considers "*Eliptocephalus*" to be a true *Paradoxides.*)

Olenellus (*Elliptocephalus*) FORD, 1877, American Journ. Sci., 3d ser., Vol. 13, pp. 265-272. (A very full description of the type species *O.* (*E.*) *asaphoides.*)

Olenellus FORD, 1878, American Journ. Sci., 3d ser., Vol. 15, p. 130, footnote. (Discusses the generic relations of *Olenellus,* as represented by *O. asaphoides,* and Paradoxides as represented by *P. aculeatus* and *P. kjerulfi.*)

Olenellus FORD (in part), 1881, American Journ. Sci., 3d ser., Vol. 22, pp. 250-259. (As discussed throughout the paper the genus *Olenellus* includes forms now referred to *Elliptocephala, Mesonacis,* and *Olenellus.*)

Olenellus WALCOTT (in part) [not HALL], 1886, Bull. U. S. Geol. Survey, No. 30, pp. 162-166. (Described and discussed. As discussed the genus includes forms now referred not only to *Olenellus* but to *Elliptocephala, Callavia,* and *Peachella.* On pages 622-623 are given reasons for rejecting *Elliptocephala* as a generic name.)

Olenellus HOLM (in part), 1887, Geol. Fören. i Stockholm Förhandl., Bd. 9, Häfte 7, p. 498-499. (Described in Swedish. As described and discussed throughout the paper this genus includes many of the forms now placed in the family *Mesonacidae.*)

Ebenezeria MARCOU, 1888, Mem. Boston Soc. Nat. Hist., Vol. 4, p. 123. (Proposed as a new genus to replace "*Elliptocephalus*" because of the similarity of the latter genus to *Ellipsocephalus* Zenker.)

Elliptocephalus (Emmons), MARCOU, 1890, American Geologist, Vol. 5, p. 362. (Argues that "*Elliptocephalus*" has right of priority over *Olenellus.*)

Olenellus (*Mesonacis*) WALCOTT (in part), 1891, Tenth Ann. Rept. U. S. Geol. Survey, p. 637. (Merely uses *Mesonacis* as a subgenus; the forms referred to the subgenus are now placed with *Elliptocephala* and *Mesonacis.*)

Elliptocephala COLE, 1892, Natural Science, Vol. 1, p. 340. (Discussed.)

Mesonacis PEACH and HORNE (in part), 1892, Quart. Journ. Geol. Soc. London, Vol. 48, p. 236. (As defined this genus includes forms now referred to both *Elliptocephala* and *Mesonacis.*)

Olenellus Bernard, 1894, Quart. Journ. Geol. Soc. London, Vol. 50, pp. 415-416. (Discusses evidence afforded by this genus as to the systematic position of the trilobites.)

Mesonacis (*Olenellus*) Peach (in part), 1894, Idem, pp. 671-674. (As discussed in these pages this genus includes forms now referred to both *Elliptocephala* and *Mesonacis.*)

Elliptocephala (Emmons), Beecher, 1897, American Journ. Sci., 4th ser., Vol. 3, pp. 191 and 192. (Name used in discussion of genera of the *Olenidae.*)

Georgiellus Moberg, 1899, Geol. Fören. i Stockholm Förhandl., Bd. 21, Häfte 4, p. 317. (Proposed as a new genus to replace *Elliptocephala.*)

Elliptocephala (Emmons), Matthew, 1899, American Geologist, Vol. 24, p. 59. (In review of Moberg's paper [1899] considers that *Elliptocephala* should be retained.)

Olenellus (*Georgiellus*) Pompeckj, 1901, Zeitschr. Deutschen geol. Gesellsch., Vol. 53, Heft 2, p. 16. (Emmons' species is merely mentioned as "*O.* (*Georgiellus*) *asaphoides*" in the discussion of the relations between *Olenopsis* and various genera of the Mesonacidæ.)

Olenellus Lindström, 1901, Kongl. Svenska Vet.-Akad. Handlingar, Vol. 34, No. 8, pp. 12-18, and 24. (A discussion of the development of the Olenellidae is almost entirely based upon features exhibited by the type species of the genus *Elliptocephala.*)

The characters of the genus are outlined in the description of the genotype, *E. asaphoides,* which is the only known species. Observations on *Elliptocephala* are also made in the section on Mesonacidæ (pp. 244 and 247).

Genotype.—*Elliptocephala asaphoides* Emmons.

Stratigraphic range.—Lower Cambrian: Greenwich formation[1] in shales and interbedded limestones and sandstones of unknown thickness, but as far as known not over 300 feet.

Geographic distribution.—On the eastern side of the Hudson River valley, in Washington and Rensselaer counties, New York.

Young stages.—Reference is made to the younger stages of growth of this genus in the description of the development of the individual of the family Mesonacidæ, p. 236. This, with the illustrations on plates 24 and 25, will give the student the means of comparison with the young stages of other genera. The specimens in the Ford collection are now in the New York State Museum at Albany, New York.

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[1] Mr. T. Nelson Dale [1904, p. 29] gives a section of the Lower Cambrian series exposed in Rensselaer County, and part of Columbia County, New York. On pages 43 and 50 he states that this series is regarded as equivalent to the Greenwich formation of Washington County, New York, and Rutland County, Vermont. The series is also regarded as equivalent to the Vermont formation and is mapped on plate 1 of the same paper under the heading "Greenwich slate,

Observations.—*Elliptocephala* appears to be a more advanced form of the Mesonacidæ than *Mesonacis*. It has seven less segments in the thorax and the stage of large third segment is passed in the young and is lost in the adult. The five small posterior segments of *Elliptocephala* suggest that they are rudimentary segments by reversion, as in *Pædeumias* [pl. 33], and not rudimentary as the result of non-development, as in *Nevadia* [pl. 23]. From its stratigraphic position and associated fossils it is probably somewhat older than *Mesonacis vermontana* Hall.

ELLIPTOCEPHALA ASAPHOIDES Emmons

PLATE 24, FIGS. 1-10; PLATE 25, FIGS. 1-18

Elliptocephala asaphoides EMMONS, 1844, Taconic System, p. 21, figs. 1, 2, and 3. (Characterized in description of figure 1.)

Elliptocephala asaphoides EMMONS, 1846, Nat. Hist. New York, Agriculture, Vol. 1, p. 65, figs. 1, 2, and 3. (Copy of preceding reference.)

Olenus asaphoides (Emmons), HALL, 1847, Nat. Hist. New York, Paleontology, Vol. 1, pp. 256-257, pl. 67, figs. 2a-c. (Describes species and redraws the three specimens illustrated by Emmons [1844, p. 21, figs. 1, 2, and 3].)

Olenus asaphoides (Emmons), FITCH, 1849, Trans. New York State Agric. Soc. for 1849, p. 865. (Occurrence mentioned.)

Eliptocephalus asaphoides EMMONS, 1849, Proc. American Assoc. Adv. Sci., First Meeting, p. 18. (Discussed with particular reference to the generic distinction between *Eliptocephalus, Paradoxides,* and *Olenus.*)

Eliptocephalus asaphoides EMMONS, 1855, American Geology, Vol. 1, pt. 2, p. 114, figs. 1, 2, and 3; and pl. 1, fig. 18. (Described. Figures 1, 2, and 3 are copied from Emmons, 1844, figs. 1, 2, and 3, p. 21.)

Not *Paradoxides asaphoides* EMMONS, 1860, p. 87 = *Olenellus thompsoni.*

Not *Paradoxides macrocephalus* EMMONS, 1860, fig. 70, p. 88, and p. 280 = *Olenellus thompsoni.* (In the first edition of the Manual of Geology this figure was labeled *Paradoxides brachycephalus.*)

Not *Eliptocephalus (Paradoxides) asaphoides* EMMONS, 1860, p. 280 = *Olenellus thompsoni.*

Paradoxides asaphoides (Emmons), BARRANDE, 1861, Bull. Soc. Géol. de France, 2d ser., Vol. 18, pp. 273-276, pl. 5, figs. 4 and 5. (Translates into French the legend of figures 1 and 2 of Emmons [1844, p. 21] and copies figure 1 of the same paper in fig. 4, pl. 5. Figure 5 of Barrande's paper is copied from Emmons [1855, pl. 1, fig. 18]. Barrande also translates into French the description and discussion given by Hall [1847, p. 256].)

Not *Paradoxides macrocephalus* BARRANDE, 1861, Idem, pl. 5, fig. 7 = *Olenellus thompsoni.*

Vermont formation." This is apparently the first use of the term "Greenwich slate," the previous mention of the series, to which Mr. Dale refers on page 50 being the table opposite page 178 of his paper in the 19th Annual Report of the U. S. Geological Survey [1899] where no formation names are used.

Olenellus (*Olenus*) *asaphoides* (Emmons), Ford, 1871, American Journ. Sci., 2d ser., Vol. 2, p. 33. (Gives name in list of species from rocks at Troy, N. Y.)

Olenellus (*Olenus*) *asaphoides* (Emmons), Ford, 1871, Canadian Naturalist, new ser., Vol. 6, p. 210. (Copy of preceding reference.)

Olenellus (*Elliptocephalus*) *asaphoides* (Emmons), Ford, 1877, American Journ. Sci., 3d ser., Vol. 13, pp. 265-272, pl. 4, figs. 1-10. (Described and discussed in detail, both young and adult specimens being illustrated.)

Olenellus asaphoides (Emmons), Ford, 1878, American Journ. Sci., 3d ser., Vol. 15, pp. 129-130. (Note on the development of the young and on the generic relations of the species.)

Olenellus asaphoides (Emmons), Ford, 1881, American Journ. Sci., 3d ser., Vol. 22, pp. 250-259, figs. 1, 2, and 3, p. 251. (Observations on the generic relations and larval stages of the species. Figure 3 is an outline drawing of the figure given by Ford [1877, pl. 4, fig. 5].)

Olenellus asaphoides (Emmons), Walcott, 1884, Monogr. U. S. Geol. Survey, Vol. 8, pp. 36-37, pl. 21, figs. 10, 11, and 12. (Young stages of growth referred to. Figure 10 is an outline drawing based on Ford's figure [1877, pl. 4, fig. 2b], and figures 11 and 12 are similar drawings based on the cephalons of the figures given by Ford [1881, figs. 1 and 2, p. 251].)

Olenellus asaphoides (Emmons), Walcott, 1886, Bull. U. S. Geol. Survey, No. 30, pp. 168-170, pl. 17, figs. 3-8 and 10; pl. 20, figs. 3, 3a-b; and pl 25, fig. 8. (Described and discussed. The specimen represented by fig. 3, pl. 17, is redrawn in this paper, pl. 25, fig. 18; figures 5 and 6, pl. 17, are copied in this paper, pl. 25, figs. 9 and 10; fig. 7, pl. 17, is copied from Ford, 1877, pl. 4, fig. 5; fig. 8, pl. 17, is copied from Ford, 1881, fig. 1, p. 251; figs. 3a-b, pl. 20, are copied from Walcott, 1884, pl. 21, figs. 10, 11, and 12, respectively; and fig. 8, pl. 25, is copied in this paper pl. 24, fig. 10.)

Olenellus asaphoides (Emmons), Holm, 1887, Geol. Fören. i Stockholm Förhandl., Bd. 9, Häfte 7, p. 515. (Described in Swedish. The species is frequently mentioned also in the discussion of "*Olenellus kjerulfi*.")

Elliptocephalus asaphoides (Emmons), Marcou, 1888, American Geologist, Vol. 2, p. 12. (Discussed.)

Ebenezeria asaphoides Marcou, 1888, Mem. Boston Soc. Nat. Hist., Vol. 4, p. 123. (Merely proposes the new generic name for the species because of the close similarity between "*Elliptocephalus*" Emmons and *Ellipsocephalus* Zenker.)

Olenellus asaphoides (Emmons), Lesley, 1889, Geol. Survey Pennsylvania, Report P4, Vol. 2, p. 489, 10 text figures. (Figures 3, 5, 6, 7, 8, and 10 are copied without change in number from Walcott, 1886, pl. 17; and figs. 3, 3a, and 3b are copied in the same manner from Walcott, 1886, pl. 20.)

Olenellus (*Mesonacis*) *asaphoides* (Emmons), Walcott, 1890, Proc. U. S. National Museum, Vol. 12, p. 41. (Mentions discovery of entire specimens of the dorsal shield.)

Olenellus asaphoides (Emmons), MATTHEW, 1891, American Geologist, Vol. 8, p. 289 and footnote. (Suggests that the species is from a different horizon from that of "*Olenellus thompsoni*" and "*Olenellus* (*Mesonacis*) *vermontana*," and believes that *Elliptocephala* should be retained as the generic reference.)

Olenellus (*Mesonacis*) *asaphoides* (Emmons), WALCOTT, 1891, Tenth Ann. Rept. U. S. Geol. Survey, pp. 637-638, pl. 86, figs. 3, 3a-b; pl. 88, figs. 1, 1a-g; pl. 89, figs. 1, 1a; and pl. 90, figs. 1, 1a. (Discussed. Figures 3, 3a-b, pl. 86, are copied from Walcott, 1884, pl. 21, figs. 10, 11, and 12 respectively; figs. 1 and 1a, pl. 88, are copied from Walcott, 1886, pl. 17, figs. 5 and 6; fig. 1d, pl. 88, is redrawn from the specimen illustrated by Ford, 1877, pl. 4, fig. 5; figs. 1b, 1c, 1d, and 1e, pl. 88, are copied in this paper, pl. 24, figs. 3, 4, 5, and 10 respectively; the specimen represented by figure 1f, pl. 88, is redrawn in this paper, pl. 24, fig. 6; fig. 1g, pl. 88, is redrawn in this paper, pl. 24, fig. 8; figs. 1 and 1a, pl. 89, are copied in this paper, pl. 24, figs. 1 and 2 respectively; and fig. 1a, pl. 90, is copied in this paper, pl. 24, fig. 9.)

Elliptocephala asaphoides (Emmons), COLE, 1892, Natural Science, Vol. 1, pp. 340-341. (Notes on use of name.)

Olenellus asaphoides (Emmons), BERNARD, 1894, Quart. Journ. Geol. Soc. London, Vol. 50, pp. 415-416 and 423-424; fig. 3, p. 415; figs. 4a-c and 5, p. 416; and fig. 9, p. 423. (Discusses evidence afforded by this species as to the systematic position of the trilobites. Figure 3 is copied from Walcott, 1886, pl. 17, fig. 5; figures 4a-c are copied from Walcott, 1884, pl. 21, figs. 10, 11, and 12, outline drawings which were based on Ford's figures [1877, pl. 4, figs. 2, 3, and 4]. Figure 5 is copied from Walcott, 1891, pl. 88, fig. 1b; and figure 9 is a diagrammatic restoration of the cephalon figured by Walcott, 1891, pl. 90, fig. 1.)

Mesonacis (*Olenellus*) *asaphoides* PEACH, 1894, Idem, p. 671; text fig. *c*, p. 673; and pl. 32, fig. 11. (Mentioned. The figures are copied from drawings or parts of drawings given by Walcott [1891, pls. 88 and 89].)

Olenellus (*Mesonacis*) *asaphoides* (Emmons), BEECHER, 1895, American Geologist, Vol. 16, p. 176, figs. 6, 7, and 8, p. 175. (Larval stages discussed. Figure 7 is copied from Walcott, 1884, pl. 21, fig. 10, an outline drawing which was based on Ford's figure [1877, pl. 4, fig. 2b] and figure 8 is an outline drawing of the figure given by Walcott [1886, pl. 17, fig. 5].)

Georgiellus asaphoides (Emmons), MOBERG, 1899, Geol. Fören. i Stockholm Förhandl., Bd. 21, Häfte 4, p. 316, pl. 13, figs. 1a and 1b. (The species is referred to *Georgiellus,* a new genus replacing *Elliptocephala* and the figures are copied from Walcott, 1891, figs. 1 and 1a, pl. 89.)

Not *Olenellus* (*Mesonacis*) *asaphoides* ? GRABAU, 1900, Occasional papers, Boston Soc. Nat. Hist., No. 4, Vol. 1, pt. 3, pp. 667-669, pl. 34, figs. 2a-b. (Referred in this paper to *Callavia crosbyi.*)

Not *Olenellus* (*Mesonacis*) *asaphoides* BURR, 1900, American Geologist, Vol. 25, p. 45. (Referred in this paper to *Callavia crosbyi.*)

Olenellus (*Georgiellus*) *asaphoides* (Emmons), POMPECKJ, 1901, Zeitschr. Deutschen geol. Gesellsch., Vol. 53, Heft 2, p. 16. (Name used in the discussion of the relation between *Olenopsis* and various genera of the Mesonacidae.)

Olenellus asaphoides (Emmons), Lindström, 1901, Kongl. Svenska Vet.-Akad. Handl., Vol. 34, No. 8, pp. 12-18, text figs. 1-10, p. 13. (Development of cephalon discussed. Figs. 2 and 3 are copied from Walcott [1886, pl. 17, figs. 5 and 6]; figs. 5, 6, and 7 are copied from Ford, [1877, pl. 4, figs. 1, 2, and 3]; fig. 10 is drawn from the cephalon of the figure given by Ford [1877, pl. 4, fig. 5]; and figs. 8 and 9 are drawn from the cephalons of the figures given by Ford [1881, figs. 1 and 2, p. 251].)

Olenellus (*Mesonacis*) *asaphoides* (Emmons), Clarke and Ruedemann, 1903, Bull. New York State Museum, No. 65, pp. 730-732. (A list of the specimens (hypotypes) collected by Ford in the collection of the New York State Museum.)

Dorsal shield broad ovate, moderately convex. Cephalon large, semicircular in outline, about two-fifths the length of the dorsal shield; genal angles extended into spines; facial suture rudimentary or in a condition of synthesis; eyes elongate, crescentic, with ridges uniting the palpebral lobes to the anterior lobe of the glabella in the young, and in the adult a narrow furrow serves to cut off the palpebral ridge from the glabella; glabella elongate, increasing gradually in width from the occipital furrow to the greatest width on the anterior lobe; anterior lobe large, convex, broader than the posterior lobes, even in the earliest known stage of growth in which it is defined [pl. 25, fig. 9]; the three posterior lobes are subequal in size, nearly transverse and separated by distinct, short lateral furrows that are united by a shallow transverse furrow. In the young the furrows are much deeper proportionally. Occipital ring strong and well defined, when not flattened in shale it has a small median node.

Thorax with eighteen segments; body of pleuræ nearly straight, and with a broad furrow that extends out to the geniculation at the base of the strong falcate extension of the pleuræ. The five posterior segments terminate on the line of the body of the pleuræ in blunt, rounded ends that curve backward at the posterior margin; the pleural furrows are narrow and shallow. The anterior thirteen segments have a small median node near the posterior margin of their axial lobe, and each of the posterior five segments has a long, strong, tapering spine that extends back over the pygidium.

Pygidium small, transverse, and with only a trace of an anterior segment.

Surface finely granulated, and with narrow, irregular raised ridges that unite to form an irregular network over the glabella, axial, and pleural lobes of the thorax; on the cheeks and frontal limb of the cephalon the ridges radiate from the base of the eyes and the

glabella to the outer rim; on the outer rim and spines and on the falcate spinous extension of the pleuræ the ridges are subparallel to the margins.

Hypostoma elongate ovate in outline, strongly convex; anterior margin arched to conform to the outline of the interior margin of the doublure of the cephalon to which it was attached; posterior margin and side margins to the antennal groove denticulated or with six or more short, blunt projections on each side of the median line; antennal groove on the lateral margins in front of the thickened round rim and back of the subtriangular anterior lateral extension of the body along the anterior margin. The oval body is outlined posteriorly by a strong furrow on each side that extends obliquely inward and backward from the antennal furrow, and a very shallow transverse furrow that unites the posterior ends of the oblique furrows; a short, shallow, transverse furrow occurs on the space bebetween the furrow described and the denticulated posterior margin.

It is rarely that the denticulated margin can be worked out of the hard limestone matrix. This led Ford [1877, pl. 4, fig. 6] and Walcott [1886, pl. 17, fig. 10] to represent the hypostoma with a smooth posterior margin. A denticulated margin was illustrated but not described by Walcott in 1891, pl. 88, fig. 1*g*.

Dimensions.—A dorsal shield 126 mm. in length that is flattened in the shale has the following dimensions:

Cephalon:	*mm.*
Length	50
Width at base	98
Length of eye lobe	24
Length of glabella	40
Width of glabella at base	24
Width of glabella at front	31
Thorax:	
Length	70
Width at anterior segment, including spinose extension of the pleuræ	79
Width at thirteenth segment, including spinose extension	63
Width at eighteenth segment, including spinose extension	14
Width of axial lobe, anterior segment	24
Width of axial lobe, thirteenth segment	13
Width of axial lobe eighteenth segment	9
Width of pleural lobe, anterior segments	20
Width of pleural lobe, eighteenth segment	3
Pygidium:	
Length	about 6
Width at front	13

The preceding description is based on adult flattened specimens of *E. asaphoides* Emmons, as shown by fig. 1, pl. 24. In uncompressed cephalons and dorsal shield from a limestone matrix [figs. 3-7, pl. 24], the convexity is greater and the relief of the surface stronger.

FORMATION AND LOCALITY.—Lower Cambrian: Greenwich formation [Dale, 1904, pp. 29, 43, and 50, and pl. I] in thin-bedded limestones interbedded in siliceous shales at the following localities: (**35b**)[1] *adjoining the house of D. W. Reed on the roadside near the Old Reynolds Inn, 1 mile (1.6 km.) west of North Greenwich;* (**35**) western side of D. W. Reed's farm, 1.5 miles (2.4 km.) north of Bald Mountain; (**36a**) on the roadside about 3 miles (4.8 km.) northeast of North Greenwich; (**33**) on the roadside near Rock Hill Schoolhouse No. 8 in Greenwich Township; (**33b**) 1.5 miles (2.4 km.) east-southeast of North Greenwich; (**34**) a little west of the bridge over the Poultney River at Low Hampton; (**45b**) on the roadside 70 rods east of Bristol's house at Low Hampton; (**36**) 1 mile (1.6 km.) south of Shushan in the town of Jackson, 3.5 miles (5.6 km.) north of Cambridge; (**38**) .25 mile (.4 km.) north of John Hulett's farmhouse, 3 miles (4.8 km.) west of South Granville; (**38a**) 2 miles south of North Granville on the road which turns south from the road running between that village and Truthville; and (**37**) 1.5 miles (2.4 km.) south of Salem; all in Washington County, New York.

(**29a**) limestone 1 mile (1.6 km.) below the New York Central Railroad depot at Schodack Landing; and (**27**) even-bedded and conglomerate limestones on the ridge in the eastern suburb of Troy; both in Rensselaer County, New York.

(**32**) sandstone on the south slope of Stissing Mountain, Dutchess County, New York.

Genus CALLAVIA Matthew

Olenellus WALCOTT (in part) [not HALL], 1866, Bull. U. S. Geol. Survey, No. 30, pp. 162-166. (Described and discussed. As discussed the genus includes forms now referred not only to *Olenellus,* but to *Callavia, Elliptocephala,* and *Peachella.*)

Olenellus WALCOTT (in part) [not HALL], 1891, Tenth Ann. Rept. U. S. Geol. Survey, pp. 633-635. (As discussed the genus includes forms now referred to both *Olenellus* and *Callavia.*)

Cephalacanthus LAPWORTH (in part) [not LACÈPÉDE], 1891, Tenth Ann. Rept. U. S. Geol. Survey, by Chas. D. Walcott, p. 641. (Proposed as a new genus to include *Olenellus kjerulfi, O. bröggeri,* and *O. callavei.* The name was, however, preoccupied by Lacèpéde, 1802, Hist. Nat. Poiss., Vol. 3, p. 323.)

[1] This is the Reynolds Inn locality of Emmons and Fitch.

Cephalacanthus LAPWORTH (in part), 1891, Geological Magazine, Dec. 3, Vol. 8, p. 531. (Gives reasons for proposing the genus. The reference to the original place of publication of *Cephalacanthus* is given as "Geol. Mag., 1888, p. 641" it should be "Tenth Ann. Rept. U. S. Geol. Survey, by Chas. D. Walcott, 1891, p. 641.")

Holmia PEACH and HORNE (in part), 1892, Quart. Journ. Geol. Soc. London, Vol. 48, p. 236. (As defined this genus includes forms now referred to both *Holmia* and *Callavia.*)

Holmia (*Olenellus*) PEACH (in part), 1894, Idem, Vol. 50, pp. 671-674. (As discussed in these pages this genus includes forms now referred to both *Holmia* and *Callavia.*)

Callavia MATTHEW, 1897, American Geologist, Vol. 19, p. 397, footnote. (Generic name proposed to include "*Olenellus bröggeri*" Walcott and "*Olenellus callavii*" Lapworth on account of the glabella differing from that of "Olenellus (Holmia) kjerulfi.")

Holmia MOBERG (in part), 1899, Geol. Fören. i Stockholm Förhandl., Bd. 21, Häfte 4, pp. 314 and 318. (As characterized the genus includes two species now placed under *Callavia.*)

Dorsal shield broad ovate, moderately convex; cephalon broad, semicircular; marginal rim broad and continued into genal spines; posterior margin with a strong, short intergenal spine just within the genal angle and the rudimentary facial suture.

Facial sutures rudimentary or in a condition of synthesis back of the eye, but not observed in front of the eye. Eye lobes narrow, elongate-crescentiform. Glabella clavate-elongate, with the large anterior lobe contracting toward the front. The three posterior lobes are not strongly defined, the occipital ring has a strong median spine extending back over the thorax.

Hypostoma convex, broad in front, narrowing to the broadly rounded, smooth posterior margin; crossed within the narrow posterior margin by a sulcus subparallel to the margin, also a flattened ridge anterior to which a strong groove is outlined on each side; antennal furrows, *x x*, fig. 2, pl. 27, gently arched inward on the lateral margins.

Thorax with fifteen to eighteen segments. Axial lobe convex, with an elongate node or spine at the center. Pleural lobes broad and passing gradually into the broad, curved extensions of each segment; pleural furrows extending from the side of the axial lobe out to the beginning of the curved terminations of the pleuræ.

Pygidium small, transverse, and with a transverse groove near the anterior margin; lateral lobes not developed.

Surface minutely granular and with irregular network of very narrow, irregular anastomosing ridges.

Genotype.—Olenellus (*Holmia*) *bröggeri* Walcott.

Stratigraphic range.—Lower Cambrian (Georgian) terrane in a zone about 75 feet thick that is 270 feet below the zone of *Paradoxides hicksi* [Walcott, 1891, pp. 260-261]. *Callavia bröggeri* occurs in numbers 2 and 4 of the section.

Geographic distribution.—Atlantic Coast Province, *Callavia bröggeri* occurs about the head of Conception Bay, Newfoundland, and *C. crosbyi* and *C. burri* in eastern Massachusetts near Weymouth. *Callavia callavei* Lapworth is from central Shropshire, England.

Observations.—Moberg [1899, p. 318, footnote] called attention to the variation of *Holmia bröggeri* Walcott, *H. callavei* Lapworth, and *H. lundgreni* Moberg from *Holmia kjerulfi* Linnarsson, and raised the question as to whether they should not form a new genus or subgenus. With the new material furnished by *Callavia crosbyi,* a form closely related to *C. bröggeri* Walcott, formerly referred to *Holmia,* and by *Holmia rowei* Walcott, I decided to group *Olenellus* (*Holmia*) *bröggeri* Walcott [1891], *Olenellus callavei* Lapworth [1891, pp. 530-536], and the two species described in this paper as *Callavia crosbyi* and *C. burri* under a new genus. Later I found (hidden away in a footnote[1]) that Dr. G. F. Matthew had proposed the name *Callavia* to include the same species on account of the character of the glabella.

Callavia bröggeri [pl. 27, fig. 1] differs from *Holmia kjerulfi* Linnarsson [pl. 27, fig. 7], the genotype of *Holmia,* in having the first lobe of the glabella constricted in front instead of expanded; in the presence of a strong occipital spine, and in having broad, sickle-shaped extensions of the pleuræ [fig. 6] instead of sharp, spine-like terminations as in *H. kjerulfi* [fig. 7].

The glabella appears to be of a more primitive type than that of *Holmia,* in this respect resembling the glabella of *Nevadia* [pl. 23, fig. 3], and that of the young of *Elliptocephala* [pl. 25, figs. 13 and 14].

Callavia has the intergenal spines in the adult close to the genal spines, and forming a part of the posterior margin of the cephalon, instead of a distinct spine crossing it half way between the glabella and genal spine, as in *Holmia.*

Comparing *Callavia* and *Holmia* as to the stages of development shown by their various parts, we find that the glabella of *Callavia* is more primitive, the intergenal spine and pleuræ less primitive.

The comparisons between *Callavia* and *Wanneria* are made under observations on the former genus [p. 247].

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[1] Matthew, 1897, p. 397, footnote.

CALLAVIA BICENSIS, new species

PLATE 41, FIGS. 9, 9A

Cephalon longitudinally, broadly semi-elliptical; strongly convex, with the eye lobes and front lobe of the glabella rising abruptly from the cheeks; marginal border slightly rounded and separated from the cheeks by a shallow, rounded groove; it broadens somewhat at the genal angles, where it is prolonged into spines; the posterior marginal border is narrow and convex beside the occipital ring, from whence it flattens out and broadens before uniting with the border at the genal angle; an oblique thickening occurs where the low ridge extending from the posterior end of the eye crosses the margin.

Glabella with a large, convex anterior lobe that rises abruptly from the narrow space between it and the anterior marginal border; this lobe has two short and slightly defined furrows on each side that originate near the front margin of the palpebral ridge; the posterior of the two furrows extends inward on a line almost directly across the lobe and the anterior furrow extends inward subparallel to the rounded lateral margin of the lobe; a narrow, low ridge extends all about the front of the lobe very much in the same manner as a similar ridge in *Callavia crosbyi* [pl. 28, fig. 1]; the posterior lateral angles of the lobe are connected to the palpebral lobe by a strong, rounded ridge; the second glabellar lobe is narrow and arched slightly backward at each end so as to nearly enclose the ends of the third lobe, which is thus shortened, but it is still transversely longer than the fourth lobe; the fourth lobe is transversely shorter than the second and third, also a little wider; the second, third, and fourth lobes all arch backward, and are very faintly defined across the center of the glabella. The glabella is narrow at the base, expanding to where it unites with the palpebral lobe, from whence it contracts toward its front margin; this gives an outline somewhat similar to that of *Callavia bröggeri* [pl. 27, fig. 1]. Occipital ring about the same width and length as the fourth glabellar lobe; it is marked by a small median node that rises from its highest point at the posterior margin. Palpebral lobes narrow, elevated, and gently arched from their connection to the first glabellar lobe to opposite the glabellar furrow between the occipital ring and fourth glabellar lobe; the posterior end of the lobe is about as far from the side of the glabella as the width of the fourth glabellar lobe; the palpebral lobes, although elevated, do not rise to the level of the

median line of the glabella; they slope rather abruptly inward to the nearly flat interpalpebral area. Visual surface of eye narrow and arching around beneath the outer margin of the palpebral lobe. Cheeks of medium width and sloping rapidly, with a gentle curvature, from the base of the eye and the anterior glabellar lobe to the intermarginal furrow; a facial suture is indicated back of the eye by a narrow ridge extending from the posterior end of the eye obliquely outward and backward so as to cross the posterior marginal border obliquely about two-thirds of the distance from the occipital ring to the genal angle.

The portions of the thorax preserved show that the thoracic segments had a strongly arched axial lobe with a median spine on each segment; the pleural lobes are relatively short and of the same character as those of *Callavia crosbyi* [pl. 28, fig. 4]; the pleural furrow is rather broad next to the axial lobe, from whence it narrows out to the rather short falcate termination. The segments shown on the specimen illustrated belong to the middle portion of the thorax; several of the other segments have been crowded up beneath the cephalon, as shown by the breaking away of a portion of the cheek.

Surface of the cephalon and of thoracic segments ornamented by an extremely fine network of raised ridges, such as characterize the surface of *C. crosbyi* [pl. 28, fig. 7]. There is also a series of very fine irregular ridges radiating from the base of the eye and anterior lobe of the glabella outward to the intermarginal furrow.

Dimensions.—The type specimen of a cephalon has a length of 13 mm., with a width of 19 mm. The proportions of other parts of the cephalon are illustrated by fig. 9, pl. 41, which is based on a photograph enlarged two diameters.

Observations.—This species is described from a single specimen found in the conglomerate limestone at Bic. It shows an entire cephalon and several of the middle segments of the thorax. The illustration is drawn from a cast made in the natural matrix from which the specimen was broken in breaking the limestone. Numerous fragments of large thoracic segments similar to those of *Callavia bröggeri* were found in the same boulder of limestone, but there were no traces of the cephalon except bits of the cheeks and palpebral lobes. The ends of the pleuræ are illustrated by figs. 10 and 10*a*, pl. 41.

Callavia bicensis differs from *C. crosbyi* in the outline of the cephalon and glabella, proportions of palpebral lobes, glabella, and cheeks. It does not have the great occipital spine of *C. bröggeri* or the tapering, conical glabella of *C. burri* [pl. 28, fig. 9].

The associated fossils are *Micromitra nisus* Walcott, *Botsfordia cœlata* (Hall), *Hyolithes, Discinella,* fragments of large species of *Callavia,* and *Protypus* sp. (?)

FORMATION AND LOCALITY.—Lower Cambrian (2r) *a limestone boulder enclosed in a conglomerate of probable Upper Cambrian age, in a railroad cut 2 miles (3.2 km.) west of the railroad station at Bic, Province of Quebec, Canada.*

CALLAVIA BRÖGGERI Walcott

PLATE 27, FIGS. 1-6

Olenellus bröggeri WALCOTT, 1888, Name proposed at exhibition of specimens at the International Geological Congress, London.

Olenellus bröggeri WALCOTT, 1888, Nature, Vol. 38, p. 551. (Name used in geologic section.)

Olenellus (Mesonacis) bröggeri WALCOTT, 1889, American Journ. Sci., 3d ser., Vol. 37, pp. 378-380. (Description of localities and horizon in geological section).

Olenellus (Mesonacis) bröggeri WALCOTT, 1890, Proc. U. S. National Museum, Vol. 12, p. 41. (Describes species and compares it with other species of *Olenellus.*)

Holmia ? brœggeri (Walcott), MARCOU, 1890, American Geologist, Vol. 5, pp. 370-371. (Contends that this species is not a true *Olenellus,* and refers it tentatively to *Holmia.*)

Olenellus (Holmia) bröggeri WALCOTT, 1891, Tenth Ann. Rept. U. S. Geol. Survey, pp. 638-640, pl. 91, fig. 1; pl. 92, figs. 1, 1a-h. (Described and discussed. Figure 1, pl. 92, is copied in this paper, pl. 27, fig. 1, and pl. 44, fig. 4. Figures 1c, 1d, 1e (in part), 1g, and 1h, pl. 92, are copied in this paper, pl. 27, figs. 5, 6, 2, 4, and 3 respectively.)

Cephalacanthus bröggeri LAPWORTH, 1891, Tenth Ann. Rept. U. S. Geol. Survey, by Chas. D. Walcott, p. 641. (Compared with "*Cephalacanthus callavei.*")

Callavia bröggeri MATTHEW, 1897, American Geologist, Vol. 19, p. 397, footnote. (New genus proposed.)

Olenellus (Holmia) brœggeri (Walcott), POMPECKJ, 1901, Zeitschr. Deutschen geol. Gesellsch., Vol. 53, Heft 2, pl. 1, fig. 10. (Mentioned frequently on pages 14-17 in a discussion of the relations between *Olenopsis* and various genera of the Mesonacidae. Figure 10 is copied from Walcott, 1891, pl. 91, fig. 1.)

Olenellus bröggeri (Walcott), BERNARD, 1894, Quart. Journ. Geol. Soc. London, Vol. 50, p. 423. (Calls attention to the occipital spine as a modification of the "dorsal organ" of *Apus.*)

Holmia bröggeri (Walcott), PEACH, 1894, Idem, pp. 672 and 673. (Refers to this species in discussion of *Olenellus.*)

Not *Olenellus (Holmia) bröggeri* BURR, 1900, American Geologist, Vol. 25, pp. 43-45. (Referred in this paper to *Callavia crosbyi.*)

Not *Olenellus (Holmia) bröggeri* GRABAU, 1900, Occasional Papers, Boston Soc. Nat. Hist., No. 4, Vol. 1, pt. 3, pp. 662-664, pl. 33, figs. 1a-j. (Referred in this paper to *Callavia crosbyi.*)

The new material of this species that has been added to our collection since the specific description was published in 1891 [Walcott, pp. 638-641] shows that the intergenal spines of a small cephalon 5 mm. in length are long and slender, and extend a little beyond the points of the genal spines. The glabellar furrows are very faint and the occipital spine slender. The generic relations of the species have been discussed under the genus *Callavia* [p. 276].

FORMATION AND LOCALITY.—Lower Cambrian: (**41**) sandstone[1] in a railroad cut 1 mile (1.6 km.) west of the Manuels Brook railway bridge; (?) a decomposed arenaceous limestone 1,200 feet (366 m.) west of the railway bridge mentioned in **41**; in railway cuts 300 feet (91 m.) west (**5p**), 1 mile (1.6 km.) west (**5s**), and 1.5 miles (2.4 km.) west (**5r**) of Manuel Station; (**41a**) a compact, thin-bedded limestone beneath Topsail Head; (**42**) a horizon nearly corresponding to the base of the Manuels Brook section, on Brigus Head; and at (**5t** and **5u**) slightly different horizons[2] on Redrock Point, near Chapple Cove, Hollywood Point; all on Conception Bay, Newfoundland.

(**5n**) shale on Smith Point in Smith Sound, Trinity Bay, Newfoundland.

CALLAVIA BURRI, new species

PLATE 28, FIGS. 9-10

Olenellus sp. BURR, 1900, American Geologist, Vol. 25, p. 45. (Notes occurrence of an unidentified species of *Olenellus*.)

Olenellus sp. GRABAU, 1900, Occasional Papers, Boston Soc. Nat. Hist., No. 4, Vol. 1, pt. 3, pp. 665-667, pl. 34, figs. 1a-b. (Described as possibly belonging to a new subgenus of *Olenellus*. The specimen represented by figure 1a is redrawn in this paper, pl. 28, fig. 9.)

Cephalon semicircular in outline, moderately convex in its fine, quartzitic sandstone matrix; bordered by a moderately broad, slightly convex rim that is separated from the cheeks by a faintly defined furrow; genal angles, as now known, extended in small, short, flattened spines; posterior border narrow and rounded next to the occipital ring and gradually widening to where it curves into the outer border at the genal angle; it has a slight undulation midway of its length, but is not interrupted by the crossing of the ridges of intergenal spines; intermarginal furrow narrow and slightly de-

[1] See the section given by Walcott [1891b, pp. 260-261] for the stratigraphic position of the species in the section on Manuels Brook.

[2] Locality No. 5u is about 175 feet higher than 5t, which is 20 feet above the base of the section.

pressed. Glabella convex, conical, and strongly lobed; dorsal furrow shallow and interrupted about the anterior lobe by a very narrow second furrow that separates a narrow ridge from the glabella; the anterior lobe of the glabella tapers from the base toward the narrowly rounded front and its base is broadly wedge shaped, owing to the backward slope of the anterior pair of furrows; the second and third lobes are united about the ends of the second pair of furrows, while the fourth lobe is clearly defined by the occipital furrow; occipital ring convex, of uniform width, and without a median node or spine. Palpebral lobe united to the postero-lateral base of the anterior glabellar lobe by a narrow ridge; it is about one-third the length of the cephalon, and at its posterior end it is distant about one-half of its length from the glabella; opposite its posterior end and adjoining the dorsal furrow next to the end of the fourth glabellar lobe a small prominent tubercle breaks the surface of the area within the palpebral lobe. Cheeks gently convex and divided only by a narrow intergenal ridge that extends from the base of the palpebral lobe diagonally outward to the posterior marginal border about midway of its length.

Surface.—The surface is similar to that of *Callavia crosbyi*, except that the meshes of the reticulated network of narrow ridges are somewhat finer and more like those of the right side of fig. 7, pl. 28, than the meshes on the left side.

Dimensions.—A cephalon 24 mm. in length has a width at the base of 47 mm. Length of glabella 17 mm.; width of glabella at base 10 mm. Width of glabella at base of anterior lobe inside the narrow outer ridge 7 mm. Length of palpebral lobe 8 mm. Distance of palpebral lobe from glabella at anterior end 2 mm.; at posterior end 6 mm.

Observations.—Of this species only a few specimens of the cephalon are known. Its outline is similar to that of *Callavia crosbyi*, except that in the specimens thus far seen the genal spines are very much smaller, and there is no evidence of an intergenal spine. The marginal rim is less distinctly defined than in *C. crosbyi;* the palpebral lobes are shorter; and the glabella proportionally shorter, more conical, and more distinctly lobed.

Callavia burri differs from *C. bröggeri* as it does from *C. crosbyi*, and it does not have the great occipital spine of the former species.

FORMATION AND LOCALITY.—Lower Cambrian: (**9n**) associated with *Callavia crosbyi* in the dark, purplish siliceous shale of the Weymouth formation on Pearl Street, North Weymouth, Norfolk County, Massachusetts.

CALLAVIA CALLAVEI (Lapworth)

PLATE 42, FIGS. 1-2

Olenellus callavei LAPWORTH, 1888, Geological Magazine, new series, Dec. 3, Vol. 5, p. 485. (Name proposed.)

Olenellus callavei LAPWORTH, 1888, Nature, Vol. 39, p. 212. (Copy of preceding reference.)

Olenellus (*Holmia*) *calevi* (Lapworth), WALCOTT, 1891, Tenth Ann. Rept. U. S. Geol. Survey, p. 635. (Refers species to *Holmia* as result of having seen specimens of it.)

Cephalacanthus callavei LAPWORTH, 1891, Tenth Ann. Rept. U. S. Geol. Survey, by Chas. D. Walcott, pp. 640-641. (Compared with "*Cephalacanthus bröggeri*" and "*C. kjerulfi.*")

Olenellus (*Holmia*) *callavei* LAPWORTH, 1891, Geological Magazine, Dec. 3, Vol. 8, pp. 530-536, pl. 14, figs. 1-25, and pl. 15. (Described and discussed, with special reference to its relations to *Olenellus kjerulfi* and *O. bröggeri.*)

Olenellus (*Holmia*) *callavei* (Lapworth), COLE, 1892, Natural Science, Vol. 1, pp. 344 and 345. (Discussed.)

Callavia callavii MATTHEW, 1897, American Geologist, Vol. 19, p. 397, footnote. (New genus proposed.)

Dr. Lapworth gives a very full description and illustration of the fragments representing this species, and a diagrammatic restoration based apparently on my restored figure of *C. bröggeri* [Walcott, 1891, pl. 91, fig. 1].

Callavia callavei differs from *C. bröggeri* in its stronger genal and intergenal spines and shorter occipital spine, form of the glabella, and lateral extensions of the pleuræ. It may be that other differences will appear if better specimens become available for comparison, or as the two species are very closely related, it may be found that they are specifically more nearly identical than now seems probable.

FORMATION AND LOCALITY.—Lower Cambrian: near the base of the Comley sandstone (Hollybush series) in a purplish-red arenaceous limestone, Comley quarry, on the flanks of Little Caradoc, near Church Stretton, Central Shropshire, England.

CALLAVIA CARTLANDI Raw, MSS.

PLATE 42, FIGS. 3-4

Olenellus (*Holmia?*) *cartlandi* RAW, 1909, MSS. received from Mr. Frank Raw, University of Birmingham, England, December 17, 1909.

This species is founded on a single specimen found loose in the quarry at Comley in Shropshire. It occurs on a characteristic piece of chocolate and green limestone of the *Callavia callavei* bed of the quarry that has been subjected to considerable abrasion and weath-

ering. The two photographs of the specimen show the characters of the species, and as Mr. Raw will soon publish a detailed description, I will only quote from his manuscript the comparisons made with the closely allied and associated species *C. callavei* Lapworth to show how it differs from the latter species:

Head.

(1) The head is much broader in proportion.

(2) It is greatly produced in a postero-lateral direction, this part of the cheeks being very extensive.

(3) The posterior margin of the cheeks are wavy in outline, quite different from the simple sigmoid curve of *O.* (*H.*) *callavei.*

(4) The occipital furrows are stronger and less oblique.

(5) There is no indication of a strong occipital spine such as in *O.* (*H.*) *callavei* modifies so greatly the occipital ring.

Thorax.

(6) The trilobation in the thorax gives vastly different proportions between axis and limbs, the former being less than half the width of the latter, the contrast being due to a great lateral extension of the pleuræ in this form.

(7) The outline—wavy—of the pleuræ is quite different, as is also their initial directions (somewhat forwards) from the axial rings.

(8) The falcate extremities of the pleuræ are much longer and more backwardly directed.

Of these distinguishing characters, the most striking are the great relative breadth due to an extension of the limbs throughout and showing itself especially in the entirely different proportion of the thoracic pleuræ—slender, instead of thick-set, and the shape of the pleuræ—wavy, of 3 curves, and starting from the axis somewhat forwards, instead of simply sigmoid and starting backwards.

Callavia cartlandi is similar to *C. burri* [pl. 28, fig. 9] in not showing an occipital spine, or intergenal spines in its broad postero-lateral cheek, and in the narrowing of the glabella. It is not improbable that these two species will be found to represent a distinct form that may, with the discovery of better specimens, be placed under a new subgenus or genus.

Callavia cartlandi differs strongly from *Wanneria walcottanus* [pl. 30, fig. 2] in the form of the anterior lobe of the glabella and the furrows on the pleuræ of the thoracic segments.

I am indebted to Mr. Frank Raw, of Birmingham University, England, for casts of the type specimens and for the opportunity to read his preliminary manuscript notes on the species.

FORMATION AND LOCALITY.—Lower Cambrian: near the base of the Comley sandstone (Hollybush series) in a purplish-red arenaceous limestone, Comley quarry, on the flanks of Little Caradoc, near Church Stretton, Central Shropshire, England.

CALLAVIA CROSBYI, new species

PLATE 28, FIGS. 1-8

Olenellus (*Holmia*) *bröggeri* BURR, 1900, American Geologist, Vol. 25, pp. 43-44. (Specimens from North Weymouth described and discussed.)

Olenellus (*Mesonacis*) *asaphoides* BURR, 1900, Idem, p. 45. (Distorted specimens of the cephalon found at North Weymouth are doubtfully identified with this species and characterized.)

Olenellus (*Holmia*) *bröggeri* GRABAU, 1900, Occasional Papers Boston Soc. Nat. Hist., No. 4, Vol. 1, pt. 3, pp. 662-664, pl. 33, figs. 1a-j. (Described and discussed.)

Olenellus (*Mesonacis*) *asaphoides ?* GRABAU, 1900, Idem, pp. 667-669, pl. 34, figs. 2a-b. (Identification based on distorted cephalons of *Callavia crosbyi.*)

Metadoxides magnificus ? GRABAU, 1900, Idem, p. 670, pl. 34, figs. 4-6, (Fragments of spines referred to the species with reservation.)

Callavia crosbyi is so similar to *C. bröggeri* that the description of the latter, except where the two forms differ in details, will suffice. These differences are: the stronger posterior marginal border; the presence of a narrow, clearly defined ridge about the anterior glabellar lobe in *C. crosbyi;* a stronger, broader pleural furrow in the thorax; and a relatively shorter extension of the pleuræ beyond the end of the furrow. The pygidium of *C. crosbyi* is not well known, as the only specimen showing it is crushed and poorly preserved. The hypostomæ [pl. 28, fig. 6, and pl. 27, fig. 2] are similar as far as known.

Callavia crosbyi differs from *C. burri* in the outline and details of the glabella, larger palpebral lobes, and proportions of the glabella and cheeks.

The surface is finely granular and beautifully ornamented with a network of fine, irregular, anastomosing ridges, as shown by fig. 7, pl. 28. On the left side the elongate meshes of the network are seen as they occur on the broad margin of the cephalon and on the right side the fine network of the cheek below the eye; this surface extends over the glabella, the posterior border of the cephalon, and the thoracic segments, except on the curved extensions of the pleuræ where the meshes are coarser.

The longest cephalon in the collection has a length of 58 mm. and width of 126 mm. This indicates that the dorsal shield attained a length of 32 cm. or more.

FORMATION AND LOCALITY.—Lower Cambrian: (9n) associated with *Callavia burri* in the dark, purplish siliceous shale of the Weymouth formation on Pearl Street, North Weymouth, Norfolk County, Massachusetts.

CALLAVIA ? NEVADENSIS, new species

PLATE 38, FIGS. 12-14.

Olenellus gilberti WALCOTT (in part) [not MEEK], 1884, Monogr. U. S. Geol. Survey, Vol. 8, p. 29, pl. 9, fig. 16, and pl. 21, fig. 13 (not fig. 16a, pl. 9, which is referred in this paper to *Olenellus fremonti;* nor figure 14, pl. 21, which is referred in this paper to *Olenellus gilberti*). (Described. Figures 16 and 13 are copied in this paper, pl. 38, figs. 12 and 14 respectively.)

Olenellus gilberti WALCOTT (in part) [not MEEK], 1886, Bull. U. S. Geol. Survey No. 30, pp. 170-180, pl. 19, figs. 2c, d, f, and g (not pl. 18, figs. 1, 1a-b; pl. 19, figs. 2, 2a, 2b, 2k; pl. 20, fig. 4; and pl. 21, figs. 1 and 1a = *Olenellus gilberti;* and not pl. 18, fig. 1c; pl. 19, figs. 2e, 2h, 2i; pl. 20, figs. 1, 1a-i, 1k-m; and pl. 21, figs. 2 and 2a = *Olenellus fremonti*). (The description and discussion given includes reference to specimens now referred to *Callavia nevadensis.* Figure 2d, pl. 19, is copied in this paper, pl. 38, fig. 13; figure 2c is copied from Walcott, 1884, pl. 21, fig. 13; and figure 2g is copied from Walcott, 1884, pl. 9, fig. 16.)

Olenellus gilberti WALCOTT (in part) [not MEEK], 1891, Tenth Ann. Rept. U. S. Geol. Survey, pl. 84, figs. 1e and 1g; pl. 85, figs. 1e and g (not pl. 84, figs. 1, 1a-c; pl. 85 figs. 1b-d; and pl. 86, fig. 4 = *Olenellus gilberti;* and not pl. 84, figs. 1d and 1f; pl. 85, figs. 1, 1a, and 1f; and pl. 86, figs. 1, 1a-i, 1k-m = *Olenellus fremonti*). (No text reference. Figures 1e and 1g, pl. 84, are copied from Walcott, 1886, pl. 19, figs. 2d and 2f; fig. 1e, pl. 85, is copied from Walcott, 1886, pl. 19, fig. 2g; and fig. 1g, pl. 85, is copied from Walcott, 1884, pl. 21, fig. 13.)

Of this species only fragments of the cephalon and thorax are known. These I referred to *Olenellus gilberti* [1884, 1886, and 1891], but in restricting the latter species to the characters shown by the type specimens [pl. 36, figs. 1-3] the specimens from Prospect Mountain are separated and now referred to *C. nevadensis.* They are distinguished from *O. gilberti* by the broader space between the glabella and frontal rim, short eye lobes, and converging sides of the glabella, particularly those of the large frontal lobe. The glabella is similar to that of *C. burri* [pl. 28, fig. 9], but the marginal borders differ materially in the two species.

Callavia nevadensis is associated with numerous fragmentary specimens of *Olenellus fremonti* [pl. 37] and *Peachella iddingsi* [pl. 36, fig. 17].

The reference to the genus *Callavia* is on account of the tapering glabella and slender anterior glabellar lobe.

FORMATION AND LOCALITY.—Lower Cambrian: Pioche formation at the following localities: (51 and 52) *at the summit of Prospect Mountain, Eureka District, Eureka County;* (30) on the west slope of the Highland Range, 8 miles (12.8 km.) north of Bennetts Springs. and about 8 miles (12.8 km.) west of Pioche, Lincoln County; and

(313g) in the Groom Mining District, at the south end of the Timpahute Range, near the line between Nye and Lincoln counties; all in Nevada.

Genus HOLMIA Matthew

Paradoxides FORD (in part), 1878, American Journ. Sci., 3d ser., Vol. 15, p. 130, footnote. (Discusses the generic relations of *Paradoxides* as represented by *P. kjerulfi* and *P. aculeatus* with *Olenellus* as represented by *O. asaphoides*.)

Olenellus HOLM (in part), 1887, Geol. Fören. i Stockholm Förhandlingar, Bd. 9, Häfte 7, pp. 498-499. (Described in Swedish. As described and discussed throughout the paper the genus includes many of the forms now placed in the family Mesonacidæ.)

Gen ? MATTHEW, 1888, Canadian Record Sci., Vol. 3, pp. 75-76. (Linnarsson's species, *Paradoxides kjerulfi*, is discussed as the representative of a new genus intermediate between *Paradoxides* and *Olenellus*, and Matthew says: "It is to be hoped that his countrymen will see reason to connect Holm's name with this new genus.")

Holmia MARCOU, 1890, American Geologist, Vol. 5, pp. 365-366. (Linnarsson's species is discussed and Marcou accepts Matthew's suggestion [1888, p. 76] and places the species under *Holmia*.)

Holmia MATTHEW, 1890, Trans. Roy. Soc. Canada, Vol. 7, Sec. 4, p. 160, footnote. (Points out differences between *Olenellus kjerulfi* and the American species of *Olenellus*, and proposes the generic name *Holmia*.)

Cephalacanthus LAPWORTH (in part) [not LACÈPÉDE], 1891, Tenth Ann. Rept. U. S. Geol. Survey, by Chas. D. Walcott, p. 641. (Proposed as a new genus to include *Olenellus kjerulfi*, *O. bröggeri*, and *O. callavei*. The name, however, was preoccupied by Lacèpéde, 1802, Hist. Nat. Poiss., Vol. 3, p. 323.)

Cephalacanthus LAPWORTH (in part), 1891, Geol. Mag., Dec. 3, Vol. 8, p. 531. (Gives reasons for proposing the genus. The reference to the original place of publication of *Cephalacanthus* is given as "Geol. Mag., 1888, p. 641" it should be "Tenth Ann. Rept. U. S. Geol. Survey, by Chas. D. Walcott, 1891, p. 641.")

Holmia COLE, 1892, Natural Science, Vol. 1, p. 344. (Discussed. In the legend of figure 3, p. 343, *Holmia* is placed as a subgenus of *Olenellus*.)

Holmia PEACH and HORNE (in part), 1892, Quart. Journ. Geol. Soc. London, Vol. 48, p. 236. As defined this genus includes forms now referred to both *Holmia* and *Callavia*.)

Holmia (*Olenellus*) PEACH (in part), 1894, Quart. Journ. Geol. Soc. London, Vol. 50, pp. 671-674. (Compares certain characters of *Holmia* with those of *Olenellus* and *Mesonacis*. As discussed in these pages, however, the genus includes forms now referred to both *Holmia* and *Callavia*.)

Holmia BEECHER, 1897, American Journ. Sci., 4th ser., Vol. 3, p. 191. (Considers facial sutures of *Holmia* as in a condition of synthesis. Places *Holmia* in family *Paradoxinæ*.)

Holmia FRECH, 1897, Lethæa geognostica, pt. 1, Lethæa Palæozoica, Bd. 2, p. 41. (Considers *Holmia* and *Olenopsis* Bornemann as identical.)

Holmia MOBERG (in part), 1899, Geol. Fören. i Stockholm Förhandl., Bd. 21, Häfte 4, p. 318. (Briefly characterizes genus. As characterized the genus includes species now referred to *Callavia*.)

Holmia MATTHEW, 1899, American Geologist, Vol. 24, p. 59. (Reviews Moberg's paper [1899] and notes two types placed under *Holmia*.)

Holmia WELLER, 1900, Ann. Rept. Geol. Survey New Jersey for 1899, pp. 50-51. (Discussed.)

Holmia POMPECKJ, 1901, Zeitschr. Deutschen geol. Gesellsch., Vol. 53, Heft 2, pp. 14-17. (*Olenopsis* is compared with *Holmia* and other genera of the Mesonacidæ.)

Holmia LINDSTRÖM, 1901, Kongl. Svenska Vet.-Akad. Handlingar, Bd. 34, No. 8, p. 24. (Considers *Holmia* an eyeless trilobite, with beginning suture.)

Holmia is characterized by intergenal spines in the adult, a uniform series of thoracic segments and a small more or less transverse pygidium with only traces of transverse furrows indicating segments in the median lobe.

Genotype.—*Paradoxides kjerulfi* Linnarsson, 1871.

The only American species of the genus I recognize is *Holmia rowei* Walcott.

Stratigraphic range.—Lower Cambrian. In Scandinavia the *Holmia kjerulfi* zone is just beneath the *Paradoxides* bearing strata. In Sweden it is overlain by the *Paradoxides tessini* zone [Holm, 1887, p. 514], and in Norway by the *P. ölandicus* zone [*Idem*, p. 514].

Holmia rowei Walcott occurs low down in the Lower Cambrian in association with *Nevadia weeksi* Walcott.

Geographic distribution.—Scandinavia in Europe; southwestern Nevada in the United States.

Observations.—The generic relations and position of *Holmia* in the Mesonacidæ are considered in observations on the Mesonacidæ [p. 247].

From the occurrence of *Holmia kjerulfi* just beneath the *Paradoxides* zone in Scandinavia with associated genera closely allied to those in the *Paradoxides* fauna it is probable that the genus occurs in the upper portion of the Lower Cambrian in western Europe. In the southwestern United States, in Nevada, *Holmia rowei* is found over 4,500 feet below the zone of *Olenellus gilberti*. I strongly suspect that there is a lost interval in the Scandinavian section between the zone of *Holmia kjerulfi* and *Paradoxides ölandicus* that may represent a portion of the section between *Olenellus* and *Holmia* in Nevada. That *Olenellus* is not found in Scandinavia also strengthens this view, as *Olenellus* is very characteristic of the higher beds of the Lower Cambrian in both eastern and western North America.

Holmia [pl. 27, fig. 7] differs from *Callavia* [pl. 27, fig. 1] in having an expanded frontal glabella lobe; in its spinose extensions of the pleura; and small occipital spine. From *Wanneria* [pl. 30, figs. 2 and 6] it varies in not having a great spine on the fifteenth segment, and in having spinose extensions of the pleuræ. The latter character is similar to that in the thorax of *Elliptocephala* [pl. 24, fig. 1] and *Mesonacis* [pl. 26, fig. 1].

Holmia follows *Mesonacis* and *Callavia* in the scheme of classification of the Mesonacidæ because it is considered that the thorax indicates a stage of development slightly more advanced than in those genera. The latter still retain the partially developed posterior segments that appear to have disappeared in *Holmia*.

Dr. G. F. Matthew [1899, p. 59] in his review of Moberg's paper [1899, pp. 309-348] mentions that there are two types under *Holmia* as arranged by Moberg [1899, pp. 314 and 318], the first two species mentioned after *Holmia kjerulfi* being distinguished from the genotype by a difference in the number of the segments in the thorax, and possessing a conical in place of a club-shaped glabella. The species are *H. bröggeri* Walcott and *H. callavei* Lapworth. These forms are now included in the genus *Callavia*.

HOLMIA KJERULFI Linnarsson

PLATE 27, FIG. 7

Paradoxides kjerulfi LINNARSSON, 1871, Öfversigt af Kongl. Vet. Akad. Förhandlingar, pp. 790-792, pl. 16, figs. 1-3. (Described and discussed.)

Paradoxides kjerulfi (Linnarsson), KJERULF, 1873, Om grundfjeldets og sparagmitfjeldets maegtighed i Norge. 2. Sparagmitfjeldt, p. 83, text figs. 1-5. (No text reference.)

Olenellus kjerulfi (Linnarsson), BRÖGGER, 1878, Nyt Mag. for Naturvid., Bd. 24, p. 44. (Mentioned.)

Paradoxides kjerulfi FORD, 1878, American Journ. Sci., 3d ser., Vol. 15, p. 130, footnote. (Discusses generic relations of *Paradoxides* as represented by *P. kjerulfi* with *Olenellus* as represented by *O. asaphoides*.)

Paradoxides ? kjerulfi (Linnarsson), FORD, 1881, American Journ. Sci., 3d ser., Vol. 22, pp. 255-258, text fig. 10, p. 256. (Gives a diagrammatic figure of the cephalon, and discusses the relation of the species to *Olenellus asaphoides* and of *Paradoxides* to *Olenellus*.)

Olenellus kjerulfi LINNARSSON, 1883, Sveriges Geol. Unders., Ser. C, No. 54, pp. 18-20, pl. 3, figs. 12-17. (Describes and illustrates specimens from Andrarum.)

Paradoxides kjerulfi (Linnarsson), WALCOTT, 1886, Bull. U. S. Geol. Survey, No. 30, p. 178, pl. 20, fig. 2. (Compares occular ridge and facial suture back of the eyes with those features in *Olenellus gilberti*. Figure 2 is an outline drawing of the figure given by Linarsson [1871, pl. 16, fig. 2].)

Olenellus (?) *kjerulfi* (Linnarsson), MATTHEW, 1886, American Journ. Sci., 3d ser., Vol. 31, pp. 472-473. (Identifies species from Newfoundland and expresses doubt as to generic reference.)

Olenellus kjerulfi (Linnarson), HOLM, 1887, Geol. Fören. i Stockholm Förhandl., Vol. 9, Häfte 7, pp. 493-522 (499-512 in particular). (Described and discussed in Swedish, figuring a complete restoration of the dorsal shield [pl. 14, fig. 2] which has been widely copied, see pl. 27, fig. 1 of this paper.)

Paradoxides (*Gen.* ?) *kjerulfi* MATTHEW, 1888, Canadian Record Sci., Vol. 3, pp. 75-76. (The species is discussed as the representative of a new genus intermediate between *Paradoxides* and *Olenellus* and Matthew says: "It is to be hoped that his countrymen will see reason to connect Holm's name with this new genus.")

Holmia kjerulfi (Linnarsson), MARCOU, 1890, American Geologist, Vol. 5, pp. 365-366. (The species is discussed and Marcou accepts Matthew's suggestion [1888, p. 76] and places the species under *Holmia*.)

Olenellus (*Holmia*) *kjerulfi* (Linnarsson), WALCOTT, 1891, Tenth Ann. Rept. U. S. Geol. Survey, p. 635, pl. 86, fig. 2; and pl. 93, fig. 2. (The figure on plate 86 is copied from Walcott, 1886, pl. 20, fig. 2; figure 2, pl. 93 is copied from Holm, 1887, pl. 14, fig. 2.)

Cephalacanthus kjerulfi LAPWORTH, 1891, Tenth Ann. Rept. U. S. Geol. Survey, by Chas. D. Walcott, pp. 640-641. (Compared with "*Cephalacanthus callavei.*")

Olenellus (*Holmia*) *kjerulfi* (Linnarsson), COLE, 1892, Natural Science, Vol. 1, p. 343, text fig. 3. (Gives outline figure of the restoration of the dorsal shield by Holm, 1887, pl. 14, fig. 2.)

Holmia (*Olenellus*) *kjerulfi* PEACH, 1894, Quart. Journ. Geol. Soc. London, Vol. 50, p. 671, pl. 32, fig. 12. (Mentioned. Figure 12 is copied from Holm, 1887, pl. 14, fig. 2.)

Olenellus kjerulfi (Linnarsson), KOKEN, 1896, Die Leitfossilien, p. 7, text fig. 2. (Reproduces restoration of dorsal shield by Holm [1887, pl. 14, fig. 2]. On page 352 the species is placed under *Mesonacis*.)

Olenellus (*Holmia*) *kjerulfi* (Linnarsson) FRECH, 1897, Additional plates inserted in 1897 in Lethæa geognostica, pt. 1, Lethæa Palæozoica, Atlas, pl. 1a, fig. 13. (Figure 13 is copied from Holm, 1887, pl. 14, fig. 2.)

Holmia kjerulfi (Linnarsson), MOBERG, 1899, Geol. Fören. i Stockholm Förhandl., Bd. 21, Häfte 4, p. 318, pl. 13, fig. 3. (Mentioned at several places in the text. The figure is copied from Holm, 1887, pl. 14, fig. 2.)

Holmia kjerulfi LINDSTRÖM, 1901, Kongl. Svenska Vet.-Akad. Handlingar, Vol. 34, No. 8, p. 57. (Calls attention to the "maculæ" on the hypostoma.)

Dr. Holm's memoir [1887, pp. 493-522] on this species is so comprehensive and so well illustrated that I shall not attempt to reproduce it further than to illustrate his restoration of the dorsal shield [pl. 27, fig. 7].

The most nearly related species is *Holmia lundgreni* Moberg [pl. 40, figs. 4-7]. It differs from the latter in many details and, as

pointed out by Moberg [1899, p. 321], the two species belong to different stratigraphic horizons. *H. kjerulfi* is found in the "greywacke" below the zone containing *Paradoxides ölandicus* Sjogren. *H. lundgreni* Moberg has been found only in the Lower Cambrian sandstone.

The only American species, *Holmia rowei* [pl. 29], differs in so many characters that it is unnecessary to make comparisons between the two species.

The associated fossils at Tomten are *Obolella mobergi* Walcott, *Obolella (Glyptias) favosa* Linnarsson, and *Arionellus.*

Dr. G. F. Matthew [1886, p. 472] identified "*Olenellus (?) kjerulfi*" from New Brunswick and Newfoundland. In his catalogue of species in the Cambrian Rocks of eastern Canada [1904, pp. 260-278] he does not record the "*O. (?) kjerulfi*" under *Olenellus* or *Holmia*. The specimens are not in the Matthew collection at the University of Toronto, Canada, and under date January 6 and March 18, 1910, Dr. Matthew writes that he doubts if there is any material representing *Holmia* in the collection in St. John, as his notes were based on fragments.

Formation and Locality.—Lower Cambrian: (1) [Holm, 1887, p. 512] at Andrarum and Gislöf, Province of Skäne, Sweden.

(2) [Linnarsson, 1871, p. 790] at Tomten in Ringsaker, near Lake Mjösen; and (3) [Holm, 1887, p. 512] at Kletten; both in Norway.

(4) [Holm, 1887, p. 512] below Kyrkberget, on the shore of Great Uman Lake, Parish of Stensele, Lapland.

HOLMIA LUNDGRENI Moberg

Plate 40, Figs. 4-7

Olenellus lundgreni Moberg, 1892, Om Olenellusledet i sydliga Skandinavien, p. 3. (Specimens exhibited at 14th meeting of Skandinavian naturalists at Copenhagen discussed.)

Holmia lundgreni Moberg, 1899, Geol. Fören. i Stockholm Förhandl., Bd. 21, Häfte 4, pp. 321-329, pl. 14, figs. 1-14. (Described and discussed. A plaster cast of the specimen represented by figures 2a-b is figured in this paper, pl. 40, figs. 4 and 4a.)

Holmia lundgreni Lindström, 1901, Kongl. Svenska Vet.-Akad. Handlingar, Vol. 34, No. 8, p. 57. (Calls attention to "maculæ" on hypostoma.)

Only fragments of this species have been found, but these fortunately include one nearly entire cephalon [pl. 40, fig. 4]. All the specimens occur in a hard, compact, fine-grained sandstone. Through the courtesy of Dr. Moberg I received casts of the typical specimens described by him, also a few good fragments, of which three are

illustrated by figs. 5, 6, and 7, pl. 40. By the aid of these specimens and the casts and Dr. Moberg's very detailed descriptions the following brief description is drawn up:

Cephalon semicircular, strongly convex. Width a little less than one-half the length; marginal rim broad, flattened and separated from the cheeks by a shallow furrow; it widens from the front toward the genal angles and is probably produced into strong, flattened genal spines; posterior marginal rim about as wide as the rim in front of the glabella; it is faintly defined by a narrow, shallow furrow. Glabella widening a little from the occipital ring to the anterior end of the eye lobes where it expands into the large anterior lobe; the latter rises abruptly from just within the marginal rim and curves over to the level plane along the median line of the glabella; the glabella is marked by three pairs of lateral furrows joined across the glabella by a fainter furrow. The size and position of the furrows and the glabellar lobes are shown by figs. 4 and 5. The occipital ring is subequal in width to the fourth lobe of the glabella; it has a small, pointed median tubercle at the posterior margin. The palpebral lobes start from the postero-lateral portion of the large anterior glabellar lobes, and arch backward to a point opposite the front of the occipital ring; they are elevated nearly to the plane of the median line of the glabella and leave a depressed space between them and the dorsal furrow beside the glabella; sometimes a small intergenal spine is indicated at the end of a narrow elevated line extending from about the end of the occipital furrow. Dr. Moberg states that approximately parallel to this line is another fainter line, which extends from the posterior part of the eye, that he is inclined to consider an obliterated facial suture. He also noted traces of a similar line in front of the eye. The cheeks rise rapidly from the furrow within the marginal rim to the base of the eye.

The hypostoma is shown by fig. 6. No traces of spines or tubercles are shown on any specimens I have seen of the back and lateral margins, and Dr. Moberg did not note any marginal spines.

The median lobe of the thoracic segments is distinctly separated from the pleural lobes; a strong median spine with an elongated base occurs on many of the fragments of the median lobe; on other specimens a small tubercle is all that is seen, Dr. Moberg draws the conclusion from this that the anterior segments had small, weak spines, and that the spines increased in strength on the middle segments; the pleural lobe of the middle segments extend out directly

for about one-half their length and then curve evenly outward and backward, and narrow gradually to a point; the pleuræ are thus distinguished sharply from those of *Holmia kjerulfi* [pl. 27, fig. 7]; pleural furrow oblique, clearly marked, and deepest near the interior end.

Pygidium with a nearly circular outline without transverse furrows; its marginal rim is narrow on its anterior end, increasing slightly in width toward the posterior side where it narrows rapidly to the posterior median line, and thus gives a notched appearance to the posterior margin.

The surface is marked by irregular, fine ridges that form a more or less irregular network.

The largest cephalon has a length of 28 mm., width 54 mm., convexity about 10 mm.

Observations.—This species is most closely related to *Holmia kjerulfi* [pl. 27, fig. 7]. It differs in the outline of the glabella, genal angles, pleuræ of thoracic segments, and hypostoma. The outline of the glabella is intermediate between that of *Holmia* [pl. 27, fig. 7] and that of *Callavia* [pl. 27, fig. 1].

The fossils found in association with this species are, according to Moberg [1899, p. 329], a patelloid shell and *Hyolithes degeeri Holm.*

Formation and Locality.—Lower Cambrian: a block of sandstone (**390v**) collected west of Tumbyholm, north-northeast of Smedstorp, west of Simrisham, Province of Kristianstad, Sweden [Moberg, 1899, p. 328].

Dr. Moberg [1899, p. 329] states that he also found this species south from Gladsax Church.

HOLMIA ROWEI, new species

Plate 29, Figs. 1-11

Holmia rowei Walcott, 1908, Smithsonian Misc. Coll., Vol. 53, No. 5, p. 189. (Name used in No. 12 of section; the species does not occur in No. 3, nor in the Waucoba Spring section, pp. 187-188. The specimens identified with this species from 3 of the section are referred in this paper to *Olenellus argentus* and to *Olenellus gilberti;* those from 3d of the Waucoba section [pp. 187 and 188] are referred to *Wanneria gracile;* and those from 1d and 2j [p. 186] are not specifically identified.)

Dorsal shield elongate oval, rather strongly convex over the cephalon and less so over the thorax and pygidium. Cephalon semicircular in outline, strongly convex, one-third the length of the dorsal shield; bordered by a strong, rounded rim that is continued

into strong, long genal spines that are nearly as long as the thorax; the posterior border is broad, but not as convex as the frontal border; it narrows toward the base of the glabella and shows a decided tendency to curve with a varying angle at the intergenal angle [figs. 1, 5, 6, and 10, pl. 29]; the intermarginal furrow is narrow and rounded inward on the sides and in front, and rather more distinctly impressed within the posterior border. Glabella convex, elongate, gradually expanding from the occipital segment to the widest portion of the anterior lobe, dorsal furrow deep on the sides and in front; the anterior lobe is transverse, widest near its base, gradually curving on the sides to the rather sharply rounded front margin; the anterior and third pair of furrows extend from the central third of the glabella obliquely forward and terminate at the dorsal furrow; the second pair terminate inside so that the second and third lobes unite and enclose it [fig. 6]; usually the space between the end of the glabellar furrow and the dorsal furrow is very narrow, and it is often broken through [figs. 1, 2]; occipital ring separated from the glabella by two lateral furrows that are similar, when the shell is not too much flattened, to the glabellar furrows; the occipital ring is broad, convex, and with a long, strong median spine that curves backward over the axial lobe of the thorax to about the sixth segment; the base of the spine is strong and, in large specimens, extends nearly across the occipital ring. The cheeks arch up from the intermarginal furrow to the base of the eye, broadening back of the eye and narrowing toward the front margin so as to form only a narrow space of slightly variable width in different specimens between the glabella and the intermarginal furrow. The palpebral lobes are narrow, elongate, and gently arched outward and backward from the dorsal furrow beside the posterior lateral margin of the first glabellar lobe; they terminate a short distance from the dorsal furrow opposite the occipital furrow, thus giving only a slight divergence between their anterior and posterior ends; they are elevated to about the same height as the center of the glabella and slope rapidly into the depressed interpalpebral area, the drop to the cheeks is very abrupt, and gives only a narrow space for the visual surface of the eye. The only trace observed of a facial suture is an elevated line on the cast of the interior of a flattened cephalon; the line starts at the posterior end of the palpebral lobe and extends backward a short distance before curving outward toward the marginal rim, which it crosses obliquely at about the same place as in *Callavia bröggeri* [pl. 27, fig. 1].

Thorax with sixteen segments of the same character; the body of the thorax lies well within the long genal spines, owing to the shortness of the spinous extensions of the pleuræ; its sides are subparallel back to the tenth segment, where they begin to arch inward toward the small pygidium; axial lobe convex, about the same width as the pleural lobes, and narrowing gradually in width, a small elongate, median node, with a base as long as the width of the segment, occurs on each segment, and there is a low, rounded elongate tubercle on each side that is much like that on the axial segment of *Holmia kjerulfi* [compare fig. 4, pl. 29, with fig. 7, pl. 27]; an elongate, subtriangular tubercle next to the dorsal furrow on the anterior side of the segment is also well shown by fig. 5; usually the elongate tubercles of the axial lobe have disappeared by compression of the test; pleural lobes nearly flat from the dorsal furrow out to their curved spinose extensions where they arch gently downward; each pleura has a broad, strong furrow that is broadest next to the dorsal furrow from whence it narrows very gradually to just within the curved terminal spinous extension of the pleuræ. The posterior margin of the spinous extension is arched forward from the posterior margin of the pleuræ, which gives a beaked or slightly hooked outline to the termination of the pleuræ.

Pygidium small; width at the anterior margin and length subequal; the sides extend slightly outward from the anterior margin and terminate in short spines; the posterior margin is slightly arched backward at the center and inward on each side toward the base of the postero-lateral spines; axial lobes with one anterior transverse ring that appears to bend backward along the outer margins and extend into the terminal spines; back of the transverse ring a subtriangular termination of the axial lobe, of equal width and length, occupies the central area; it does not reach the posterior margin, and it has no traces of transverse rings or furrows; with the possible exception of the rounded outer marginal rim there are no indications of pleural extensions of the rings across the smooth space between the axial lobe and outer margins; the anterior ring shown by fig. 11 is the forward extension of the first ring that slipped beneath the terminal segment of the thorax.

Surface strongly granular on the outer rim of the cephalon [fig. 7], finely granular over most of the test, and with irregular network of fine elevated ridges that may give a pitted appearance in some places [fig. 8] where the ridges are crowded, or an open pattern with elongate meshes on the cheeks and segments.

Dimensions.—A dorsal shield 44.75 mm. in length has the following dimensions:

	mm.
Cephalon:	
Length	16.
Length of glabella	13.
Length of eyelobe	6.5
Width at posterior margin	30.
Width of glabella at posterior margin	8.
Width of glabella at broadest part of anterior lobe	10.
Thorax:	
Length	26.
Width at first segment	23.
Width of axial lobe at first segment	9.
Width of axial lobe at last segment	2.5
Width of pleural lobe at first segment	7.
Pygidium:	
Length	2.75
Width	2.5

The preceding description is based on adult specimens from 40 mm. to 50 mm. in length. The largest cephalon in the collection has a length of 30 mm.; width 50 mm. This indicates a dorsal shield of about 85 mm. in length. One young stage of growth is partly illustrated by a broken cephalon 1.5 mm. in length in which the outline [fig. 9] is rounded; glabella cylindrical, with the base of the frontal lobe continuous with the strong palpebral segment; this may be compared with the stage of *Elliptocephala asaphoides* represented by fig. 14 of pl. 25.

Observations.—Fragments of this species occur abundantly in association with *Nevadia weeksi* in hard, shaly sandstones deep down in the Lower Cambrian (Georgian) section of southwestern Nevada. In America it is the oldest species of the genus *Holmia,* and in development its position in the Mesonacidæ appears to be after the forms with imperfectly developed posterior thoracic segments: *Nevadia, Mesonacis,* and the slightly more specialized *Callavia.*

The generic relations of *Holmia rowei* to the genotype *H. kjerulfi* are very close as may be seen by comparing the illustrations on pl. 29 with fig. 7, pl. 27. The eye lobes are of the same character, as are the other parts of the cephalon; each species has sixteen thoracic segments that terminate in narrow arching spines; the pygidia are small and of the same type. The occipital spine of *H. rowei* is longer than that of *H. kjerulfi.* The specific differences are in the details of the cephalon, such as the relation of the anterior lobe of the glabella to the frontal border; the longer occipital and genal

spines and more arched pleural spines of *H. rowei* and the outlines of the pygidia.

Formation and Locality.—Lower Cambrian: (1f) arenaceous shales of the Silver Peak Group, forming No. 12 of the Barrel Spring section [Walcott, 1908*c*, p. 189], 3 miles (4.8 km.) northwest of Barrel Spring, which is 10 miles (16 km.) south of the town of Silver Peak, Esmeralda County, Nevada.

WANNERIA, new genus

Dorsal shield large, broadly oval in outline. Cephalon about two-fifths of the length of the dorsal shield, transversely semicircular in outline with genal angles extended into strong spines; marginal border strong; cheeks broad; glabella elongate, semicylindrical and with four lobes, the anterior being the largest and expanded slightly or not at all beyond the line of the sides of the glabella; palpebral lobe connected to the anterior lobe of the glabella; it is short and relatively small in the adult [pl. 30, fig. 2; pl. 31, fig. 3] and increasing in length with the decrease in the size of the cephalon [pl. 30, figs. 3, 4; pl. 31, figs. 3, 1, 2, 4, 7, 8; pl. 38, figs. 19, 22].

Thorax with seventeen segments; median lobe strongly convex; pleural lobe broad and with the pleuræ extended into falcate ends that curve more and more backward until the posterior pairs nearly enclose the pygidium; pleural furrow broad, next to the axial lobe, and extending out about one-half the length of the pleura.

A small median, elongate tubercle occurs on the axial lobe of each segment, that becomes a strong, long, median spine on the fifteenth segment in old, large specimens [fig. 11, pl. 30]. It is small in younger individuals [fig. 10, pl. 30].

Pygidium small, subcircular, transverse where it joins the thorax and notched at the posterior center.

Surface with irregular network of very fine, irregular ridges that form very fine meshes over the greater part of the outer surface of the dorsal shield and hypostoma; the meshes are elongated on the marginal border of the cephalon and genal spines subparallel to the margin, while on the doublure of the thoracic pleuræ the meshes are more or less transverse [pl. 31, fig. 12], also on the pygidium [pl. 30, fig. 8].

Dimensions.—Two of the species of the genus, *W. walcottanus* and *W. halli*, grow to a large size, equal to that of any species of the Mesonacidæ. The former species is known to have reached a length of 17.6 cm. with a width of 15 cm. at the genal angles. Fragments of *W. halli* indicate a length for the dorsal shield of 15 cm.

Young stages of growth.—Nothing is known of the younger stages of growth of the genotype, *W. walcottanus* [pl. 30], but of the closely related species, *W. halli* [pl. 31], there are examples of a number of the younger stages of growth of the cephalon. These show that in the youngest stage of growth known [pl. 31, fig. 8] the form is much like that of the young of *Pædeumias transitans* [pl. 32, fig. 1, pl. 25, fig. 22], and *Elliptocephala asaphoides* [pl. 25, fig. 10]. The most notable changes resulting from increase in size are the diminution in size and length of the palpebral lobes [pl. 31, figs. 8, 7, 4, 2, 1, 3], the separation of the genal from the intergenal spines [pl. 31, figs. 8, 6, 4, 1], and the widening of the glabella back of the first lobe [pl. 31, figs. 8, 5, 7, 4] until its sides are sub-parallel; the change in form of the first or anterior lobe of the glabella is shown by figs. 8, 5, 7, 4, 2, 1, of pl. 31. Due allowance should be made for the expansion or widening of the anterior convex lobe as the result of flattening by compression in the shale.

Genotype.—*Olenellus* (*Holmia*) *walcottanus* Wanner.

The generic name is given in honor of Prof. Atreus Wanner, of York, Pennsylvania, who first described the type species.

Stratigraphic range.—Lower Cambrian (Georgian). The genotype occurs in the York formation, *Olenellus* zone, in the upper portion of the Lower Cambrian terrane, and *W. halli* occurs in the same zone in the Montevallo shale. *W. gracile* is found about 2,000 feet down in the St. Piran formation of the Lower Cambrian of Alberta, Canada, and 1,450 miles to the south in Nevada it occurs 1,200 feet or more below the zone of *Olenellus gilberti,* which corresponds to about the horizon of *Wanneria halli* and *W. walcottanus* in Alabama and Pennsylvania, respectively.

Geographic distribution.—The genotype occurs in an east and west belt across the central parts of York and Lancaster counties, Pennsylvania. *W. halli* is found in central Alabama, and *W. gracile* in Nevada and Alberta, Canada.

Observations.—The cephalon is similar in generic characters to that of *Elliptocephala, Mesonacis, Pædeumias, Olenellus,* and *Holmia,* but differs from that of *Callavia* in having a more expanded anterior glabellar lobe, and in not having a large occipital spine. The thorax has seventeen segments of the *Callavia bröggeri* type [pl. 27, fig. 1], in that the segments continue of a uniform width out to where the margins converge into a strong backward curving point, but they differ in having a broad pleural furrow of the *Olenellus thompsoni* type [pl. 35, fig. 1], instead of the narrow oblique furrow of *C. bröggeri.* The great spine of the fifteenth segment of the adult

[pl. 30, fig. 11] is not found in *Callavia* or *Holmia*. *Wanneria* also differs from *Holmia* in the character of the lateral extensions of the pleuræ. In *Holmia* the spinose extensions give quite a different aspect [pl. 27, fig. 7] from that of the extensions of *Wanneria* [pl. 30, fig. 1]. *Wanneria* differs from *Elliptocephala* [pl. 24, fig. 1], *Mesonacis* [pl. 26, fig. 1], *Nevadia* [pl. 23, fig. 1], in the characters of the thorax to such an extent that a statement of the differences is unnecessary in this place.

WANNERIA ? GRACILE, new species

PLATE 38, FIGS. 15-24

Holmia rowei WALCOTT, 1908, Smithsonian Misc. Coll., Vol. 53, No. 5, pp. 187 and 188. (The specimens listed under this name in 3d of the Waucoba section are referred in this paper to *Wanneria gracile*.)

Holmia weeksi WALCOTT, 1908, Idem, p. 189. (The specimens listed under this name in 3 of the Barrel Spring section are referred in this paper to *Wanneria gracile*.)

Cephalon semicircular in outline, moderately convex; marginal border rounded, strong in the larger, narrow and wire-like in the smaller specimens, and continued backward at the genal angles into moderately strong spines; posterior marginal border rounded and narrow at the occipital ring and slightly broader where it merges into the strong outer rim at the genal angles. In a cephalon 17 mm. in length there are no traces of an intergenal angle [fig. 21], but in one 7 mm. in length a broad angle is present and the marginal rim is thickened by an oblique, obscure intergenal ridge that was undoubtedly an intergenal spine in younger specimens [fig. 22]. An unusual specimen of the cephalon, 8 mm. in length [fig. 23], has the outer margin curved inward very much as in a very young cephalon 2 mm. in length [fig. 24]; the ridge on the test from the base of the eye out to the margin indicates the position of the intergenal spine at *x*; the genal spine is not shown on the specimen. Glabella convex, elongate, narrowing gradually from the occipital ring to the front of the first lobe; four strong furrows extend obliquely backward from each side nearly to the center where they are united by a very shallow transverse furrow; the very slight dorsal furrow about the glabella is crossed by the occular ridges that join the anterior lobe of the glabella at its postero-lateral margins; the second, third, and fourth glabellar lobes are curved slightly backward and almost pass into the flat area within the palpebral lobe; the proportions of all the glabellar lobes and the occipital ring are shown by figs. 19

and 20, also the size and length of the palpebral lobes which are elevated and joined to the first glabellar lobe by a narrow ridge. The palpebral lobe [figs. 17, 19] is short and much like that of *Wanneria walcottanus* [pl. 30, fig. 1]. From the posterior end of the palpebral lobe a narrow furrow on the interior of the test curves backward and then outward and backward to the posterior margin, following in its course the position of the facial suture of *Paradoxides spinosus* Boeck [Barrande, 1852, pl. 12, fig. 1]. Occipital ring strong, rounded, and with a small median node near the posterior margin.

The hypostoma is of the same general character as that of *Callavia bröggeri* [pl. 27, fig. 2] and *C. crosbyi* [pl. 28, fig. 6], and differs from the hypostoma of *Wanneria* [pl. 31, fig. 9] in having a smooth, rounded frontal margin.

Surface known only from a few fragments of the test adhering to the specimens illustrated by figs. 20 and 23. These show the characteristic irregular, elevated ridges of the surface of *Holmia,* also fine, rather sharp granulations. A cephalon 2 mm. in length [fig. 24] is strongly convex and with unusually elevated prominent palpebral lobes that merge into the first glabellar lobe in a manner similar to those of the young of *Elliptocephala asaphoides* [pl. 25, fig. 10].

Dimensions.—These are shown for the cephalon by fig. 21, which is reproduced from a photograph, natural size.

Observations.—This is a very interesting species of the Mesonacidæ, and it is to be regretted that there are no entire specimens of the dorsal shield. *Wanneria ? gracile* is distinguished by its slender conical glabella from *W. walcottanus.* It resembles the latter species in having short, elevated palpebral lobes connected with the first lobe of the glabella by a strong occular ridge. Its slender glabella with the narrow first lobe is more like that of *Callavia* [pl. 27, fig. 1; pl. 28, figs. 3 and 8] than that of *Wanneria* [pl. 30, fig. 1; pl. 31, figs. 1, 5, 6], which has a rounded, expanded anterior lobe to the glabella. It is not known whether there was a large spine on the thorax as in *Wanneria* [pl. 30, fig. 11]. The absence of this information and the conical outline of the anterior lobe of the glabella renders it difficult to make a positive reference of the species to *Wanneria.* The strong marginal border of the cephalon, small eyes, and the absence of an occipital spine relate it more closely to that genus than to *Callavia.* It is not improbable that entire specimens will show it to be a form intermediate between *Callavia* and *Wanneria.*

The stratigraphic position of *W. ? gracile* is in the central portion of the Lower Cambrian terrane of western Nevada and southeastern California beneath the great Archæocyathus limestone. It is associated with *Olenellus fremonti* in the massive quartzitic sandstone series 2,500 feet above the horizon of *Nevadia weeksi,* and 1,200 feet or more below the upper beds of the Lower Cambrian carrying *Olenellus gilberti.* At Vermilion Pass, Alberta, numerous specimens of the cephalon of this species [pl. 38, figs. 17-20] occur in a hard, brownish-gray sandstone of the St. Piran formation, about 2,000 feet below the Mt. Whyte formation and 250 feet above the Lake Louise formation. With the cephalon for comparison, there do not appear to be specific differences between the specimens from Nevada and Alberta, localities 1,450 miles distant from each other.

Near Resting Springs (locality No. **14p**) the following species are associated with *W. gracile:* Cystid plates, *Lingulella (Lingulepis) rowei* Walcott, *Billingsella bivia* n. sp., *Obolella vermiltonensis* n. sp., and *Olenellus fremonti* Walcott; in Nevada (locality No. **IV**): *Archæocyathus ?* sp., *Kutorgina cingulata* (Billings), *K. perugata* Walcott, *Siphonotreta ? dubia* n. sp., *Swantonia weeksi* Walcott, *Swantonia ?* sp., *Stenotheca* cf. *elongata* Walcott, *Stenotheca* cf. *rugosa* Walcott, *Ptychoparia* sp., and *Olenellus argentus* Walcott; at Vermilion Pass (locality No. **60b**): *Obolella vermilionensis* n. sp., *Orthotheca adamsi,* n. sp.

Formation and Locality.—Lower Cambrian: Silver Peak formation [see Walcott, 1908*c,* p. 185] at the following localities: (**14p**) *quartzitic sandstones near Resting (Fresh Water) Springs, which is in the southwest corner of T. 21 N., R. 8 E., on the Armagosa River;* (**8**) arenaceous shales and shaly sandstones 3 miles (4.8 km.) above Tollgate Canyon, White Mountain Range; (**53**) sandstones in the lower portion of 3d of the Waucoba Springs section [Walcott, 1908*f,* pp. 187 and 188], 1 mile (1.6 km.) east of Saline Valley, road about 2.5 miles (4 km.) east-northeast of Waucoba Springs; (**176** and **178a**) in arenaceous shales apparently lying between massive limestones carrying Archæocyathus, at the south end of the Deep Spring Valley, about 20 miles (32 km.) east-southeast of Big Pine in Owens Valley; and (**177**) shales in low hills 3 miles (4.8 km.) west of the Deep Spring Valley; all in Inyo County, California.

(**IV**) arenaceous shales 3 miles north of Valcalda Spring and 4 miles (6.4 km.) northwest of Drinkwater Mine, Silver Peak quadrangle, Esmeralda County, Nevada.

(60b) compact sandstones of St. Piran formation about 2,000 feet (610 m.) below the Mount Whyte formation and 200 to 300 feet (61-91 m.) above the Lake Louise shale, at Vermilion Pass, on the Continental Divide between British Columbia and Alberta, west-southwest of Castle on the Canadian Pacific Railway, Alberta, Canada.

WANNERIA HALLI, new species

PLATE 31, FIGS. 1-11

The cephalon, hypostoma, and fragments of the thoracic segments of this species are all that is known of it. The cephalon [pl. 31] has the same general outline and broad marginal border as that of *W. walcottanus* [pl. 30, figs. 1 and 2]. The cephalon of *W. halli* differs from that of the latter species in having a more narrow glabella in proportion to the width of the cheeks and a smaller anterior lobe. The genal angles of 27 specimens of the cephalon of *W. halli* are all advanced in the adult, and only in the young are they on a line with the posterior margin [figs. 5 and 6]. In the larger specimens [figs. 1 and 3] the intergenal angle is a right angle; this gradually changes as the cephalon grows smaller [figs. 2, 4, and 6] until the genal angles slope inward [figs. 5 and 7] and rest against the intergenal spines [fig. 8].

The palpebral lobe of the adult [fig. 3] is relatively small, less than one-third of the length of the cephalon, but with decrease in size of the cephalon the lobe increases in length [figs. 1, 2, 4, 7, and 8] until in the smallest cephalon [fig. 8] it is seven-twelfths of its length; this includes the strong, elevated ridge that unites the lobe with the anterior lobe of the glabella. The narrowing of the glabella at the posterior end of the anterior lobe is also a very striking feature of the young of *W. halli* [figs. 5, 7, and 8].

The associated hypostoma has an elongate oval body that narrows posteriorly to the neck, that connects it with the convex transverse posterior section. A deep, oblique, lateral furrow separates the body on each side from the narrow raised outer rim and the posterior section; the outer rim merges into the convex posterior section that arches about the posterior portion of the body and the posterior and lateral margins are bordered by a flattened margin that is perforated by twelve small, round holes that, when the outer edge is broken away, leave the interspaces as blunt points which form a denticulated margin. The perforated margin occurs on very small specimens and those up to 2 mm. in length. Larger specimens have a denticulated

margin, and in the still larger all traces of the perforations have disappeared, and true spines occur usually six on each side and two or four on the posterior margin, as in *Pædeumias transitans* [pl. 34, figs. 5, 6, and 7].

Fragments of thoracic segments associated with the cephalon indicate [figs. 10, 11, pl. 31] that the pleural lobes were broad, and that the pleuræ of each segment continued outward and curved gently backward, narrowing gradually to a sharp point, as in *W. walcottanus* [pl. 30, figs. 1, 10-12].

Surface very rarely preserved owing to the maceration and compression of the specimens in the fine arenaceo-argillaceous shale. The few traces of it left indicate that it was similar to that of *W. walcottanus* in having an irregular network of fine, irregular ridges over the greater part of the surface; this is shown for the latter species by figs. 12, 13, pl. 31, and for *W. halli* by figs. 10, 11, pl. 31.

Dimensions.—The largest fragment of the cephalon in the collection indicates a complete cephalon 60 mm. in length with a width of 110 mm. and a dorsal shield based on the proportions of *W. walcottanus* of about 150 mm. in length.

Reference to the younger stages of growth of this species may be found under the description of the development of the individual of the Mesonacidæ (pp. 236-243).

The specific name is given in honor of Prof. James Hall.

Formation and Locality.—Lower Cambrian: in the upper portion of the Montevallo formation at the following localities: (**56c**) *argillaceo-arenaceous shales about 1,000 feet (305 m.) northeast of town of Helena, on roadside just north of Buck Creek;* and (**164c**) 4 miles (6.4 km.) south of Helena on road to Montevallo; both in Shelby County, Alabama.

WANNERIA WALCOTTANUS (Wanner)

Plate 30, Figs. 1-12; Plate 31, Figs. 12 and 13

Olenellus (Holmia) walcottanus Wanner, 1901, Proc. Washington Acad. Sci., Vol. 3, pp. 267-269, pl. 31, figs. 1, 2; pl. 32 figs. 1-4. (Described and discussed as a new species. The specimens represented by 1, 2, and 3, pl. 32 are redrawn in this paper, pl. 30, figs. 6, 5, and 7 respectively. The specimen represented by figure 2, pl. 31, is redrawn in this paper, pl. 31, fig. 12.)

This is one of the largest species of the Mesonacidæ, and like *Callavia bröggeri* (Walcott), *C. crosbyi* Walcott, and *C. burri* Walcott, occurs in the upper portion of the North American Lower Cam-

brian terrane. It is quite abundantly represented by fragments in the collections from York and Lancaster counties, Pennsylvania, and more rarely by entire specimens. Since the original description of the species [Wanner, 1901] Professor Wanner has found specimens that prove the existence of a median spine on the fifteenth segment that in old and large dorsal shields is as strong as in large dorsal shields of *Pædeumias transitans* [compare fig. 11, pl. 30, with figs. 3 and 4, pl. 33]. On smaller dorsal shields the median spine is proportionally much less developed [see pl. 30, figs. 10 and 12]. The median spine of the fourteenth segment is short and slender, but stronger in large dorsal shields than the pointed nodes on the other segments of the thorax and the occipital segment of the cephalon.

The palpebral lobe of the adult is small, about one-third of the length of the cephalon [fig. 2], but these specimens of younger stages of growth indicate that the lobe is progressively longer [figs. 3, 4] as the cephalon decreases in size. This character is finely shown in the young of *Wanneria halli* [pl. 31].

The presence of the great spine on the fifteenth segment indicates the approach of the *Mesonacis* stage of development and the tendency to acquire the adult character of *Olenellus thompsoni* of having a large terminal telson without segments and pygidium posterior to it. The adult *W. walcottanus* resembles *Callavia bröggeri* (Walcott) and *C. callavei* (Lapworth), but differs greatly in its smaller eyes, absence of occipital spine, and presence of a great spine on the fifteenth segment.

Dimensions.—A large somewhat flattened dorsal shield from 1 mile north of Rohrerstown, Lancaster County, Pennsylvania, has a length of 17.6 cm. and a width at the genal angles of the cephalon of 15 cm. The cephalon is 6.4 cm.; thorax 10.2 cm., and pygidium 1 cm. in length. The eye lobes vary slightly in length as compared with the length of the cephalon, but the average length is one-third of the length of the cephalon. The relative proportions of other parts of the dorsal shields are well shown by fig. 1, pl. 30.

The cephalons of *Olenellus thompsoni crassimarginatus* [pl. 35, figs. 8-10] recall those of *W. walcottanus* [pl. 30], except that the latter has small eyes and an expanded anterior glabellar lobe, while the former has large eyes and a narrower anterior lobe to the glabella.

This species differs from *Wanneria halli* [pl. 31] in having a wider anterior glabellar lobe, proportionally wider glabella, narrower cheeks, with the genal angles on a line with the posterior margin of the cephalon.

FORMATION AND LOCALITY.—Upper portion of the Lower Cambrian, in the York formation: (8q)[1] *calcareous shales 2 miles (3.2 km.) northwest of the city of York, Pennsylvania, and eastward in the same band of shales across York County to the Susquehanna River.*

(12w)[2] 2 miles (3.2 km.) north of the city of Lancaster, Pennsylvania, near Fruitville, and westward at various localities to the Susquehanna River, notably 1 mile (1.6 km.) north of Rohrerstown, on the farm of Noah L. Getz.

PÆDEUMIAS, new genus

(Παιδευμα = rudiment)

The description of *Pædeumias* is included in that of the genotype *P. transitans.* I began by placing this form as a variety of *Olenellus thompsoni,* but when I came to discuss its relations to *Olenellus* it appeared desirable to give it a distinct generic and specific name, as it is a transition stage between *Mesonacis* and *Olenellus.*

Pædeumias is a *Mesonacis* or an *Olenellus* with rudimentary thoracic segments and pygidium posterior to the fifteenth segment, as one may wish to consider it. The cephalon and first fourteen segments are generically the same in the three genera. Their differences are in the dorsal shield posterior to the fourteenth segment.

Mesonacis has a spine-bearing fifteenth segment [pl. 26] with ten smaller but typical thoracic segments and a pygidium characterized by postero-lateral spines.

Pædeumias has the fourteenth segment as a median spine posterior to which there are from two to six rudimentary segments, and a rudimentary pygidium [pl. 33].

Olenellus has the fifteenth segment as a terminal telson without segments or pygidium posterior to it.

Genotype.—Pædeumias transitans Walcott.

Stratigraphic range.—Lower Cambrian (Georgian) terrane, in upper portion, in association with *Olenellus thompsoni.*

Geographic distribution.—Typical locality Georgia, Franklin County, Vermont. It has been found on the south side of the St. Lawrence River at Bic, in the Province of Quebec; at Bonne Bay, in northwestern Newfoundland; in Labrador, at L'Anse au Loup, on the Straits of Belle Isle; south of Vermont, in Lancaster and York counties, Pennsylvania; near Cleveland, in eastern Tennessee; and in Shelby County, Alabama.

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[1] Collected by Prof. Atreus Wanner.

[2] Collected by Prof. H. Justin Roddy.

PAEDEUMIAS TRANSITANS, new species

PLATE 24, FIG. 12; PLATE 25, FIGS. 19-22; PLATE 32, FIGS. 1-13; PLATE 33, FIGS. 1-5; PLATE 34, FIGS. 1-8; PLATE 44, FIG. 7

? *Paradoxides thompsoni* BILLINGS [not (HALL)], 1861, Geol. Survey Canada, Paleozoic Fossils, p. 11. (Mentions presence of a head representing *Olenellus thompsoni* at Anse au Loup. In view of the similarity between the heads of that species and *Paedeumias transitans*, and the fact that *Paedeumias transitans* has been identified from this locality in material loaned to me by the Geological Survey of Canada it is probable that the latter species is the one referred to by Mr. Billings.)

? *Barrandia vermontana* HALL (in part), 1861, Report on the Geology of Vermont, Vol. 1, p. 370, first 6 paragraphs. (Copies the paragraph given by Hall [1860, p. 117] and describes the species. The text includes reference to figures [see Hall, 1862, pl. 13, figs. 4 and 5 in following reference] now placed under *Paedeumias transitans*.)

? *Barrandia vermontana* HALL (in part), 1862, Report on the Geology of Vermont, Vol. 2, pl. 13, figs. 4 and 5 (not fig. 2 which is a true *Mesonacis vermontana*). (As stated under this reference in the synonomy of *Mesonacis vermontana*, the specimens represented by figures 4 and 5 appear to be more closely allied to *Paedeumias transitans* than to *Mesonacis vermontana*.)

? *Olenellus thompsoni* BILLINGS [not (HALL)], 1865, Geol. Survey Canada, Paleozoic Fossils, Vol. 1, p. 11. (Reprinted from Billings, 1861a, p. 11, substituting *Olenellus* for *Paradoxides*.)

Olenellus thompsoni WHITFIELD [not (HALL)], 1884, Bull. American Mus. Nat. Hist., Vol. 1, No. 5, pp. 151-153, pl. 15, fig. 1. (Described and discussed.)

Olenellus vermontana WHITFIELD [not (HALL)], 1884, Idem, pp. 152-153, pl. 15, figs. 2-4. (Discussed.)

? *Olenellus thompsoni ?* WELLER [not (HALL)], 1900, Ann. Rept. Geol. Survey New Jersey for 1899, pp. 49-51, pl. 1, figs. 9-10. (Described and discussed. Only the head of this species is figured but it appears to be referable to *Paedeumias transitans*.)

In 1892 Prof. Atreus Wanner, of York, Pennsylvania, called my attention to the presence of well-preserved specimens of what we considered to be *Olenellus thompsoni* (Hall) in argillaceous shales at York [Walcott, 1896, pp. 13 and 16, footnote]. Subsequently Dr. Charles Schuchert made a large collection for the National Museum from the localities discovered by Professor Wanner, and later the latter permitted me to study the material in his private collection, and recently sent a number of well-preserved specimens of the younger stages of growth that he had found during the past ten years. The study of all available material has resulted in discovering a curious and interesting series of changes between the protaspis

stage and the typical adult of *O. thompsoni,* that include characters of the adult forms of *Holmia, Mesonacis,* and *Olenellus,* also that a form otherwise identical with *O. thompsoni* has rudimentary thoracic segments and a *Holmia*-like pygidium posterior to the fifteenth spine-bearing segment of the thorax. For this form the name *Pædeumias transitans* is proposed. In my first notes I referred these forms to *Mesonacis,* but with better material it became evident that the rudimentary segments of *P. transitans* were quite unlike those of *Mesonacis* [compare fig. 12, pl. 24, with figs. 2 and 3 on pl. 26].

In many specimens of *P. transitans* from York two to six rudimentary segments and a small, plate-like pygidium occur beneath and posterior to the fifteenth telson-bearing segment. The rudimentary segments are very thin, without pleural lobes, and marked by a broad, simple, transverse furrow; the ends terminate abruptly with a very short spine at the posterior angle in some specimens.

The York specimens [pl. 33, figs. 2-5] are similar to those from Vermont [fig. 1, pl. 33, and fig. 1, pl. 34]. In the typical form of *Mesonacis vermontana* [pl. 26, figs. 1 and 3] there are well-defined pleural lobes back of the fifteenth segment of the thorax, and the spine on the fifteenth segment is a characteristic dorsal spine and not a terminal telson like that of *O. thompsoni* [pl. 34, fig. 9; pl. 35, fig. 1]. The spine of fig. 1, pl. 33, is nearing the last stage of the change from the *Mesonacis*-like dorsal spine to the telson of *Olenellus.* A similar specimen to this was found by Mr. Noah L. Getz one mile north of Rohrerstown, Lancaster County, Pennsylvania.

Restricting *Mesonacis* to those forms in which the segments posterior to the spine-bearing fifteenth segment are normal thoracic segments, such as represented by figs. 1, 2, and 3, pl. 26, we then refer all with the short rudimentary segments posterior to the spine-bearing fifteenth segment to the *Pædeumias* stage of development of the Mesonacidæ as *Pædeumias transitans;* this species includes not only the York specimens, but the large Vermont specimens represented by fig. 1, pl. 33, and fig. 1, pl. 34.

In two specimens collected by Professor Wanner the telson has broken away from its base so as to show the union of the rudimentary segment and the fifteenth segment [see pl. 33, figs. 2 and 5]. The telson was hollow on the under side and, when forced down on the thin, delicate rudimentary segments, pressed them out of shape, as shown in the illustrations.

The smallest known *P. transitans* from York, with rudimentary segments, has a length of 14 mm. to the end of the telson-like spine

and of 8 mm. to the fifteenth segment. This appears to have six rudimentary segments and pygidium. The largest specimen from York [fig. 10, pl. 32] has a length of 74 mm. to the end of the telson-like spine and of 47 mm. to the fifteenth segment. It has five rudimentary segments and pygidium. The largest specimen from Georgia, Vermont, has a length of 98 mm. to the fifteenth segment. The entire dorsal shield of this specimen is similar to that of *Olenellus thompsoni,* except that the fifteenth segment is not quite reduced to a telson, and three rudimentary segments and a pygidium occur back of the great median spine [pl. 33, fig. 1]. Another feature to be noted is that the surface characters of the rudimentary segments and pygidium are sharp, elevated subparallel lines, as in the genus *Paradoxides,* and unlike those of the great spine and the segments of the thorax [pl. 24, fig. 12] which form a network of irregular reticulating and inosculating elevated lines characteristic of the known adult forms of most of the Mesonacidæ. Nearly all specimens of the thorax of *P. transitans* have a sharp, elongate, median node on the posterior four to six thoracic segments [fig. 10, pl. 32]. On some of the larger specimens there is a slender, sharp node or spine at the posterior margin of the segments from the first to the eighth, and back of the eighth the base of the node or spine becomes more elongate until it extends across the full width of the segment. The hypostoma has a denticulated or spinous postero-lateral and posterior margin. The spines are short and usually blunt [fig. 7, pl. 34], but they may be sharp [fig. 5]; there are five larger ones on each side and two or three smaller and shorter ones on the back margin that are usually broken off or obscure so as to give the effect of a clear space [fig. 5] without spines. This type of hypostoma is quite abundant at the York localities, and an almost similar form occurs in Alabama.

Young stages of growth of dorsal shield.—The youngest stage of growth collected by Professor Wanner is 1 mm. in length over the cephalon [fig. 1, pl. 32]. The next stage [pl. 32, fig. 2] is 1.5 mm. in length with cephalon, five thoracic segments and a *Holmia* pygidium. At this stage the thoracic segments do not show transverse furrows on the pleural lobes and in such specimens [figs. 2 and 3] the segments are rudimentary or have not reached the fully developed stages as seen in the adult [figs. 1 to 3, pl. 34]. This immature stage of the thoracic segment occurs in the posterior segments of the adult form of *Nevadia weeksi* [pl. 23, figs. 1, 2, and 4], and represents the earliest known or *Nevadia* stage of development of

the Mesonacidæ. At the next stage recognized, fig. 6, there are ten thoracic segments, a *Holmia* pygidium, and an enlarged third thoracic segment that is typical of *Mesonacis* and *Olenellus*. In fig. 1, pl. 33, the fifteenth segment is almost a typical telson of *Olenellus thompsoni,* but there are three short rudimentary segments and a pygidium. With another slight change the segments and pygidium would disappear and a true *Olenellus thompsoni,* like that of pl. 34, fig. 9; pl. 35, fig. 1, would result.

The conclusion from the foregoing is that the thorax of *Pædeumias* passes through several stages of development of which we now have some information. These are:

First. Holmia stage.—A *Holmia* without large third segment or telson.

Second. Intermediate stage.—A form with large third segment, but without a dorsal spine on the fifteenth segment.

Third. Pædeumias.—A form with large third segment, large spine on fifteenth segment, and with segments and plate-like pygidium posterior to the fifteenth segment.

Nearly all the specimens of *Pædeumias* found at York have the typical cephalon of *P. transitans,* as shown on pl. 34, figs. 2-4. In all of these the anterior lobe of the glabella is some distance from the frontal rim of the head, while in typical *Olenellus thompsoni* [pl. 35] and *Mesonacis vermontana,* from Vermont [pl. 26, fig. 1] the anterior lobe touches the frontal rim. With this in view, all of the specimens with the rudimentary segments and pygidium from Vermont and York may be considered as the *Pædeumias* stage of development of the Mesonacidæ. The *Pædeumias* segments of the York specimens are short and without defined pleural lobes [pl. 33, figs. 2 to 5], and in this respect are similar to those of the Vermont specimen represented by fig. 1, pl. 33, and fig. 12, pl. 24.

Notes on the young cephalon from Alabama.—Specimens from the vicinity of York are all more or less compressed and flattened in the shales. A fortunate find of uncompressed specimens of the cephalon of some of the younger stages of growth associated with the adult cephalon in the Montevallo calcareo-argillaceous shales near Montevallo, Alabama, made by Mr. Charles Butts and Mr. T. E. Williard in 1906, show some interesting characters of the species not shown by the York specimens. These are illustrated by figs. 18-22, pl. 25, and may be compared directly with the young cephalon of *Elliptocephala asaphoides* on the same plate: fig. 22 with figs. 9 and 10;

fig. 21 with fig. 2; fig. 19 with fig. 4; also with the young cephalon of *Wanneria halli,* as shown on pl. 31. These all prove the close family relationship of the young of *Pædeumias, Wanneria,* and *Elliptocephala.* The description of the young cephalon drawn from the Montevallo specimens is as follows:

Description of cephalon.—Cephalon moderately convex, elongate, semicircular in outline; bounded by a narrow, wire-like, rounded rim that is continued at the genal angle into a short, slender spine; posterior border narrow and interrupted toward the genal angle by a short, sharp intergenal spine. No facial sutures are indicated on any of the specimens. Glabella about three-fourths the length of the cephalon, narrow, elongate, and with the frontal lobe about one-third of the total length; three posterior transverse lobes and an occipital ring are separated by slightly oblique furrows that penetrate nearly to the center. These three lobes and the posterior lobe or occipital ring are nearly of equal width, and each has a small central elevated node or tubercle at the posterior margin. The occipital ring is separated by a strong furrow from the narrow posterior marginal rim of the cephalon. Eye lobes elongate, extending from the large anterior lobe of the glabella to opposite the occipital ring. They arch outward so that the inner margin is about the width of the glabella from the outer margin of the glabella. The eye lobes are separated from the anterior lobe of the glabella by a narrow furrow, although, in one crushed specimen, shown by fig. 20, pl. 25, the frontal lobe of the glabella is pushed in by the strong eye lobe; the space between the outer margin and the glabella and eye lobe is broad, gently convex, and without traces of facial sutures.

A young specimen [fig. 22] about 2 mm. in length has a narrow occipital ring, three broad glabellar lobes, and with the anterior glabellar lobe almost joined to the eye lobes; the sides of the cephalon are rounded in so as to bring the genal angles within a vertical line drawn backward from the outer margin of the eye lobe. The three short lobes of the glabella appear to be extended on each side into small lateral lobes that, with the central lobe, give a segmented appearance to the cephalon. This is further increased by the eye lobes and the anterior lobe of the glabella; the side extension of the posterior lobe of the glabella is continued into large intergenal spines, nearly as long as the head, that arch outward and the curve inward. In the specimen represented by fig. 21 the tendency of the genal angles to draw in toward the base of the glabella is indicated,

also the development of the side lobes of the three posterior glabellar lobes. The tendency to segmentation of the cranidium is the same as that shown by the head of *Elliptocephala asaphoides* [pl. 25, figs. 9 and 10].

Comparisons.—Pædeumias transitans is represented both at York and in Alabama by a number of cephalons that suggest the cephalon of *Olenellus gilberti*, as found in the shales in Nevada [pl. 36, figs. 1-3]; also the cephalon of young specimens of *Elliptocephala asaphoides* [pl. 25, figs. 11-13]. They differ from *E. asaphoides* in having a larger, longer eye lobe, narrower glabella, and in the decided difference in the younger stages of growth. The cephalon of the adult of *O. gilberti* [pl. 36, figs. 1-7] is very similar, but in the younger stages of growth [pl. 36, figs. 11-14] they differ materially from *P. transitans* [pl. 25, figs. 19-22; pl. 32, figs. 1-8].

Formation and Locality.—Upper portion of the Lower Cambrian: (**25**) *dark siliceous shale at Parkers quarry, near Georgia, Franklin County, Vermont.*

In the collections of the Geological Survey of Canada are specimens of this species from Bonne Bay, Newfoundland; and from L'Anse au Loup, on the northern shore of the Straits of Belle Isle, Labrador.

(**8q**) calcareo-argillaceous and arenaceous shales 2 miles (3.2 km.) northwest of the city of York; and (**48a**) at Cutkamps quarry north of Cottage Hill, north and northeast of the city of Troy, and eastward on the strike of the shales across York County to the Susquehanna River; all in York County, Pennsylvania.

(**56l** and **12w**) 2 miles (3.2 km.) north of the city of Lancaster, Pennsylvania, near Fruitville, and westward at various localities to the Susquehanna River, notably 1 mile (1.6 km.) north of Rohrerstown on the farm of Noah L. Getz.

(**46**) upper part of Rome sandstone, 5.5 miles (8.8 km.) west of Cleveland, Tennessee.

In central Alabama numerous specimens of the cephalon have been found in the argillaceo-arenaceous Montevallo shales at the following localities: (**17a**) 1.5 miles (2.4 km.) west of Helena on the Elyton road; (**141d**) ½ mile (.8 km.) north of Helena; (**164a**) 2 miles (3.2 km.) north of Helena; (**56c**) about 1,000 feet (305 m.) northeast of Helena on roadside just north of Buck Creek; and (**164c**) 4 miles (6.4 km.) south of Helena; all in Shelby County, Alabama.

Genus OLENELLUS Hall

Olenus Hall, 1859, Twelfth Ann. Rept. New York State Cab. Nat. Hist., p. 59. (Merely places the genotype of *Olenellus* under *Olenus.*)

Olenus Hall, 1859, Nat. Hist. New York, Paleontology, Vol. 3, pt. 1, p. 525. (Copy of preceding reference.)

Barrandia Hall (in part), 1860, Thirteenth Ann. Rept. New York State Cab. Nat. Hist., p. 115. (Described and discussed as a new genus; beginning with the 5th paragraph the text is a description of "*Barrandia thompsoni.*" As described the genus includes forms now referred to both *Olenellus* and *Mesonacis.* The generic name *Barrandia* was preoccupied and Hall later [1862, p. 114] proposed *Olenellus.*)

Paradoxides Emmons, 1860, Manual of Geology, 2d ed., p. 88, fig. 70. (Illustrates a specimen of *Olenellus thompsoni* Hall as *Paradoxides macrocephalus.* In the first edition this figure was labeled *Paradoxides brachycephalus.*)

Not *Barrandia* McCoy, proposed for a genus of trilobites.

Barrandia Hall (in part), 1861, Report on the Geology of Vermont, Vol. 1, p. 369. (Copy of Hall, 1860, p. 115; the reference including species now referred to both *Mesonacis* and *Olenellus.* Beginning with the 5th paragraph the text is a description of the species "*Barrandia thompsoni*"; this is also copied from Hall [1860].)

Olenellus Hall, 1862, Fifteenth Rept. New York State Cab. Nat. Hist., p. 114. (Proposed as a new genus to replace *Barrandia* which was preoccupied by McCoy. The name had been used in Manuscript as early as 1860.)

Olenellus (Hall), Ford (in part), 1881, American Journ. Sci., 3d ser., Vol. 22, p. 251. (As discussed throughout this paper the genus *Olenellus* includes forms now referred to *Elliptocephala, Mesonacis,* and *Olenellus.*)

Olenellus (Hall), Walcott (in part), 1886, Bull. U. S. Geol. Survey, 30, pp. 162-166. (Described and discussed in its relations to other genera. As discussed the genus includes forms now referred to *Callavia, Elliptocephala,* and *Peachella.*)

Olenellus (Hall), Holm (in part), 1887, Geol. Fören. i Stockholm Förhandl., Bd. 9, Häfte 7, pp. 498-499. (Described in Swedish. As described and discussed throughout the paper the genus includes many of the forms now placed in the family Mesonacidæ.)

Olenellus Marcou, 1889, Proc. Boston Soc. Nat. Hist., Vol. 24, p. 74. (Considers *Olenellus* a synonym of "*Elliptocephalus.*")

Olenellus (Hall), Walcott, 1890, Proc. U. S. National Museum, Vol. 12, pp. 40-41. (States that *Olenellus* is stratigraphically older than *Paradoxides.*)

Olenellus Marcou, 1890, American Geologist, Vol. 5, p. 362. (Considers *Olenellus* a synonym of "*Elliptocephalus.*")

Olenellus Hall, Walcott (in part), 1891, Tenth Ann. Rept. U. S. Geol. Survey, pp. 633-635. (Discussed in its relations to other genera. As discussed the genus includes forms now referred to *Callavia.*)

Olenellus COLE (in part), 1892, Natural Science, Vol. 1, pp. 340-346. (A historical discussion of *Olenellus* and many of the other forms now placed in the family Mesonacidæ.)

Olenellus (Hall), PEACH and HORNE, 1892, Quart. Journ. Geol. Soc. London, Vol. 48, p. 236. (Defines restricted use of *Olenellus*.)

Olenellus (Hall), BERNARD (in part), 1894, Quart. Journ. Geol. Soc. London, Vol. 50, pp. 412, 419, 430. (Refers to *Olenellus* in discussing the systematic position of the trilobites, but most of the references are based on the study of forms now referred to *Elliptocephala asaphoides*.)

Olenellus (Hall), PEACH, 1894, Quart. Journ. Geol. Soc. London, Vol. 50, pp. 671-673. (Refers to certain characters in connection with a discussion of the Scottish species of the genus.)

Olenellus (Hall), BEECHER, 1897, American Journ. Sci., 4th ser., Vol. 3, p. 191. (Refers to genus in discussing classification and includes it under family *Paradoxinæ*.)

Olenellus MOBERG, 1899, Geol. Fören. i Stockholm Förhandl., Bd. 21, Häfte 4, p. 317. (Characterized. The genus is discussed frequently on pages 309-320 of the paper.)

Olenellus WELLER (in part), 1900, Ann. Rept. Geol. Survey New Jersey for 1899, pp. 50-51. (A discussion of the genus in its broader sense.)

Olenellus (Hall), POMPECKJ, 1901, Zeitschr. Deutschen geol. Gesellsch., Vol. 53, Heft 2, pp. 14-17. (*Olenopsis* is compared with *Olenellus* and other genera of the Mesonacidæ.)

Olenellus (Hall), LINDSTRÖM, 1901, Kongl. Svenska Vet.-Akad. Handlingar, Vol. 34, No. 8, p. 24. (Considers *Olenellus* an eyeless, sutureless trilobite. The discussion of the Olenellidæ on pages 12-18 is almost entirely based on features exhibited by the type species of the genus *Elliptocephala,* and a reference to those pages is therefore placed under the latter genus.)

Genotype.—Olenus thompsoni Hall, 1859.

The adult form of *Olenellus thompsoni* Hall has been described and illustrated [see Walcott, 1886, p. 167, and 1891, p. 635], but discoveries made since 1891 have added so much to our knowledge of the younger stages of growth of some species of the genus as restricted in this paper [p. 328] that a brief description of them will be given.

For convenience of reference dorsal shields from the type locality at Parkers quarry, Georgia Township, Vermont, are illustrated [pl. 34, fig. 9; pl. 35, fig. 1].

Olenellus has a large semicircular cephalon, elongate eyes, and the anterior expanded lobe of the glabella is more or less clearly united to the eye lobes by connecting ridges. The thorax has fourteen segments and an elongate terminal telson that is quite unlike the pygidium of any other genus of trilobites, but that is similar in appearance to the telson of *Limulus*. The third segment of the thorax is enlarged and extended in a strong and long pleura on each side.

The hypostoma may be almost globose and oval in outline, with smooth posterior and postero-lateral margins [pl. 38, figs. 2 and 3], or elongate oval with the margins more or less denticulated.

Development of the dorsal shield.—From the observations made in the description of *Pædeumias transitans* [p. 307] it is concluded that *Olenellus,* as now restricted is:

First.—A *Holmia* without large third segment or telson [pl. 32, figs. 1-3]. *Holmia stage.*

Second.—A form with large third segment but without a dorsal spine on the fifteenth segment [pl. 32, figs. 4-7]. *Intermediate stage.*

Third.—A *Pædeumias* with large third segment, large spine on fifteenth segment, and with rudimentary segments and plate-like pygidium posterior to the fifteenth segment [pl. 33].

Fourth.—A true *Olenellus* with large third segment, fifteenth segment a long telson, and without observable segments or plate-like pygidium posterior to the fifteenth segment [pl. 34, fig. 9; pl. 35, fig. 1]. *Olenellus stage.*

The *Nevadia* stage of *Olenellus* is unknown, unless it is represented by figs. 2 and 3, pl. 32, where the pleuræ of the thoracic segments are apparently simple and unfurrowed. It is quite probable, however, that the *Nevadia* stage has, by acceleration, been passed and lost in the development of *Olenellus.*

The telson of *Olenellus* has long attracted the attention of paleontologists. Prof. R. P. Whitfield said of it in 1884 [p. 152]:

"This feature of the pygidium is so distinctive among all other trilobites that it alone would serve as a generic distinction, and if the condensation of parts indicates development of organization this form would appear to be below even *Paradoxides* and should precede it in age."

In commenting on Whitfield's observations in 1886 I said [Walcott, 1886, p. 166]:

"From our present knowledge of these forms we reverse the application made above and regard the telson as representing the condensed parts, and the form as higher in organization and succeeding *Paradoxides* in time."

Dr. B. N. Peach [1894, p. 672] considered the telson of *Olenellus* as the homologue of the small pygidium of *Holmia* and *Mesonacis.*

Dr. John E. Marr [1896, p. 764] wrote: "The posterior segments of the remarkable trilobite *Mesonacis vermontana* are of a much more delicate character than the anterior ones, and the resemblance of the spine on the fifteenth 'body-segment' of this species to the

terminal spine of *Olenellus* proper, suggests that in the latter subgenus posterior segments of a purely membranous character may have existed, devoid of hard parts."

Dr. Charles E. Beecher [1897, p. 191], in his memoir on "Outline of the Natural Classification of the Trilobites," says of the family *Paradoxinæ*, "Most of the genera are distinguished by their long, narrow eyes . . . . but more especially by the rudimentary character of the pygidium. In *Olenellus* the pygidium is a long telson-like spine."

Geographic distribution.—Olenellus, as restricted, is found in the sediments of the Appalachian sea as *O. thompsoni* (Hall) on the eastern side of the great pre-Cambrian Algonkian North American continental area from the Straits of Belle Isle to central Alabama. On the western side it occurs as *O. canadensis* Walcott and *O. gilberti* Meek as far north in British Columbia as Kicking Horse Pass in the Rocky Mountains; in Utah as *O. gilberti* Meek in the Wasatch Mountains; in the Eureka mining district of Nevada as *O. fremonti* Walcott; in the Pioche mining district and vicinity as *O. fremonti* Walcott; and in southwestern Nevada and southeastern California as *O. fremonti, O. argentus,* and *O. ? claytoni.*

At all the American localities *Olenellus* (restricted) occurs in the upper parts of the Lower Cambrian terrane.

On the eastern side of the Atlantic Basin *O. thompsoni* is represented by the closely allied *O. lapworthi* Peach and Horn [1892, p. 236] of northwest Scotland. This locality has also given *O. reticulatus* Peach [1894, p. 665], and *O. gigas* Peach [1894, p. 666].

As far as known, *Olenellus* does not occur on the Asiatic continent. If found at all, it will probably be in sediments deposited on the outer margins of that continental area in early Cambrian time prior to the transgression of the Middle Cambrian sea over large areas of what is now Siberia, Manchuria, central and eastern China, and northern India.

OLENELLUS ? ARGENTUS, new species

PLATE 40, FIGS. 12-16

Holmia rowei WALCOTT (in part), 1908, Smithsonian Misc. Coll., Vol. 53, No. 5, p. 189 (3 of section only). (The specimens listed under this name from 3 of the Barrel Spring section are referred in this paper to *Olenellus argentus* and *Olenellus gilberti.*)

Of this species only the cephalon is known. The globose anterior lobe of the glabella, very strong marginal border, small palpebral

lobe, strongly granular surface, and strong intergenal and genal spines distinguish it from all known species. In its small palpebral lobes and tendency to develop abnormal forms [pl. 40, fig. 14] *O. argentus* resembles *O fremonti* [pl. 37, figs. 9-11]. The shagreen granulated surface is shown by fig. 16, and the occipital ring with its short, sharp, median spine by fig. 15. The pointed surface granulations have a tendency to group in lines on the genal spines, but on the cheeks and glabella there is little trace of systematic arrangement. My impression of this surface is that it was formed by the cutting into sections, by transverse furrows, of the irregular network of ridges so characteristic of the surface of most species of the Mesonacidæ, this process finally forming a large number of sharp isolated granules.

The strong genal spines and thick outer border of the cephalon are more nearly similar to those of *Peachella iddingsi* [pl. 40, figs. 17] than any other species. The generic reference is doubtful, and will remain so until more is known of the elements of the thorax and pygidium.

The stratigraphic horizon of this species is over 1,000 feet higher in the Barrel Spring section of Nevada than the horizon of *Olenellus fremonti* and *O. ? claytoni*. The associated fossils are:

Archæochyathus ?.
Kutorgina cingulata (Billings).
Kutorgina perugata Walcott.
Siphonotreta ? dubia, n. sp.
Swantonia weeksi Walcott.
Swantonia ? sp.
Stenotheca cf. *elongata* Walcott.
Stenotheca cf. *rugosa* Walcott.
Ptychoparia sp.
Wanneria ? gracile new species.

FORMATION AND LOCALITY.—Lower Cambrian: (IV) shales of No. 3 of the Silver Peak Group, Barrel Spring section [Walcott, 1908*c*, p. 189], 3 miles (4.8 km.) north of Valcalda Spring, and 4 miles (6.4 km.) west-northwest of the Drinkwater Mine, Silver Peak Quadrangle, Esmeralda County, Nevada.

OLENELLUS CANADENSIS, new species

PLATE 38, FIGS. 1-10

Olenellus canadensis WALCOTT (in part), 1908, Canadian Alpine Journal, Vol. 1, No. 2, p. 242. (Name used in list of fossils occurring in geologic section. The specimens listed include forms now referred to *Olenellus gilberti.*)

Olenellus canadensis WALCOTT (in part), 1908, Smithsonian Misc. Coll., Vol. 53, No. 5, p. 215. (Name used in section. In both cases, however, the specimens listed include forms now referred to *Olenellus gilberti.*)

Cephalon semicircular in outline, convex; bordered in large specimens by a strong, moderately convex outer marginal rim that is narrow in front of the glabella, and that gradually broadens out on each side toward the genal angle, where it is continued as a long, strong, rounded spine. The posterior marginal border is narrow, slightly rounded, and merged at the genal angle into the outer border; in some large specimens the genal angle is carried forward and an intergenal angle [fig. 1] occurs about three-fifths of the distance out from the glabella to the outer margin of the cephalon; in other specimens the posterior border extends without interruption from the glabella out to the genal spine, as shown by fig. 4. Glabella elongate, occupying the entire length of the cephalon between the anterior, rounded border and the occipital ring; the anterior lobe is nearly as long as the three posterior lobes, transversely elliptical in outline, somewhat tumid, and nearly one-third broader than the posterior lobe: the two lobes next back of the anterior lobe are united at their outer ends, the furrow between them not extending to the dorsal furrow; the posterior lobe is transverse, arching slightly forward at the ends, and about the same width as the occipital ring and the two lobes in front of it; on some of the more perfectly preserved cephalons there is a slight median node at the posterior margin of the two posterior glabellar lobes and the occipital ring [see fig. 6]. Occipital segment broad, slightly convex, and in appearance similar to the posterior lobe of the glabella.

Eye lobe short, crescentiform, narrow, extending from the base of the expanded anterior lobe of the glabella backward and opposite the two anterior, narrow lobes; the posterior end of the eye lobe is separated from the dorsal furrow beside the glabella by a narrow, elongate subtriangular tubercle that extends from opposite the second narrow glabellar lobe back nearly to the rounded posterior marginal rim of the head. Cheeks broad, moderately convex, and marked

back of the eye lobe by a raised line that extends from the base of the eye lobe backward and slightly outward to the posterior margin of the head at the intergenal angle when the latter is present: this corresponds in position to the facial suture in the genus *Paradoxides.*

Numerous fragments of the thoracic segments have been found in association with the cephalon, but nothing is known of the number of segments or the character of their axial lobe. Two fragments of the pleural portion of the segment are illustrated by figs. 9 and 10. These indicate similar characters to those of the segments of *Olenellus thompsoni* (Hall) [pls. 34 and 35].

The telson [fig. 8] is known only by fragments. It is an elongate, slender telson without segments or lateral lobes, in this respect resembling the telson of *Olenellus thompsoni* Hall [pl. 35, fig. 1] and *O. fremonti* Walcott [pl. 37, fig. 7].

Hypostoma moderately convex, broad in front and narrow toward the posterior margin. The anterior margin shows a rounded, smooth edge that fitted into a curved recess in the doublure of the head. The lateral margin forms an elevated rim for a short distance, and then curves downward to the more elevated posterior rim; the posterior marginal rim is separated from the body by a sulcus that disappears on each side; a second groove or sulcus arches across so as to represent a narrow lobe, as shown by fig. 3. A large number of more or less crushed specimens of the hypostoma were found associated with the fragments of the cephalon and thorax.

The surface of the head and the fragments of thoracic segments have the characteristic *Olenellus* marking. It forms an inosculating, fine, raised fretwork. This type of surface is beautifully shown by figs. 4 and 5, pl. 37, of this paper.

Dimensions.—The largest specimen of a cephalon has a length of 4.5 cm., and a width of 7 cm. A small head 4 mm. in length has a width of 7 cm.

Observations.—The presence of the genus *Olenellus* in the Rocky Mountain regions of British Columbia has long been known. In 1886 I identified for Dr. Geo. M. Dawson, of the Canadian Geological Survey, among the fragments of fossils found at Kicking Horse Pass, a species of *Olenellus* that appeared to be *Olenellus howelli* Meek.[1] During the summer of 1907 I visited the Kicking Horse Pass and made an examination of the strata in which *Olenellus* occurs. The preliminary study of the fragmentary material collected

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[1] This is the species that I placed with *Olenellus gilberti* [Walcott, 1886, pp. 164 and 170].

indicated that it was a species distinct from *Olenellus howelli* [= *gilberti*], and in the geological section published in 1908 [Walcott, 1908*c*, p. 242] the name *Olenellus canadensis* was used for this species. The name was also used in a second publication [Walcott, 1908*f*, p. 215].

O. canadensis differs from *O. gilberti, O. thompsoni,* and *O. fremonti* in its very short eye lobe and the tubercles back of the eye extending to the posterior margin. The fragments of this species occur in immense numbers in several horizons of the Mount Whyte formation along a line of outcrop of some 30 miles in length.

The associated species in the Mount Bosworth section are:

Nisusia festinata (Billings).
Scenella varians Walcott.
Hyolithellus.
Ptychoparia.
Agraulos.
Protypus fieldensis, new species.

At this horizon on Mount Stephen were found:

Micromitra (*Iphidella*) *pannula* (White).
Acrotreta sagittalis taconica (Walcott).
Kutorgina cingulata (Billings).
Kutorgina, sp. undt.
Nisusia festinata (Billings).
Hyolithes billingsi Walcott.
Scenella varians Walcott.
Protypus, new species.
Agraulos, sp. undt.
Ptychoparia, 2 sp. undt.

Formation and Locality.—Lower Cambrian: (**35f**) bluish-black and gray limestone of the Mount Whyte formation, about 300 feet (91 m.) below the top of the Lower Cambrian in No. 6 of field section, just above the old railway tunnel on the north shoulder of Mt. Stephen, 3 miles east of Field, British Columbia. Fragments of *Olenellus,* probably of this species, occur at the same locality as No. **35f**, but at horizons 50 feet (**57m**) and 115 feet (**57e**) below the top of the Lower Cambrian.

(**35h**) *about 375 feet (114 m.) below the top of the Lower Cambrian in gray limestone forming No. 4 of the Mount Whyte formation* [Walcott, 1908*c*, p. 214]; and (**58y**) sandstone about 200 feet (61 m.) below the top of the Lower Cambrian; both on the slopes

of Mount Bosworth, a little north of the Canadian Pacific Railway track between Stephen and Hector, British Columbia. Fragments of a large *Olenellus,* probably of this species, occur at the same locality as Nos. **35h** and **58y**, but at a horizon 400 to 600 feet below the top of the Lower Cambrian.

(**35l**) dark, bluish-gray limestone at the base of the Mount Whyte formation; and (**60c**) calcareous sandstones of the upper 20 feet of the St. Piran formation; both on the south slope of Ptarmigan Pass, at the head of the Corral Creek, 9 miles (14.4 km.) north-northeast of Laggan on the Canadian Pacific Railway, Alberta.

(**58v**) about 450 feet (137 m.) below the top of the Lower Cambrian in a brownish-gray sandstone forming No. 1 of the field section of the St. Piran formation, in the amphitheater between Popes Peak and Mount Whyte, 3 miles (4.8 km.) northwest of Lake Louise, southeast of Laggan, on the Canadian Pacific Railway, Alberta.

(**58x**) about 300 feet (91 m.) below the top of the Lower Cambrian in the sandstones of the St. Piran formation, just below the big cliff on the east shoulder of Castle Mountain, north of Castle, on the Canadian Pacific Railway, Alberta.

OLENELLUS ? CLAYTONI, new species

PLATE 40, FIGS. 9-11

Olenellus claytoni WALCOTT (in part), 1908, Smithsonian Misc. Coll., Vol. 53, No. 5, p. 189. (Name used in No. 6 of section. The specimens listed include forms now referred to *Olenellus gilberti.*)

Of this species forty-eight specimens of the cephalon and two of the hypostoma are in the collection. The cephalon is characterized by having a glabella constricted at the third pair of furrows, from whence it widens to the large, expanded anterior lobe. The palpebral lobes are large and long like those of *O. thompsoni* [pl. 34]. I was at first inclined to place *O. claytoni* with *O. fremonti* [pl. 37], but the shorter palpebral lobes and different outline of the glabella of the latter led me to separate the two forms. The outline of the glabella is more like that of *Wanneria walcottanus* [pl. 30, fig. 2] and small cephalon of *Elliptochephala asaphoides* [pl. 24, fig. 6], but in specimens of the *O. ? claytoni* of the same size this similarity is not present.

A small cephalon 2 mm. in length has very strong connecting ridges that merge into the expanded anterior lobe of the glabella so that it appears much like the young cephalon of *Olenellus lap-*

worthi [pl. 39, fig. 4] and *Pædeumias transitans* [pl. 32, fig. 8], except that the glabella is more expanded at the first lobe in *O. claytoni.*

Dimensions.—The largest cephalon in the collection has a length of 13 mm., width 28 mm. The relative proportions of the different parts are shown by figs. 9 and 10, pl. 40. Fig. 10 is compressed laterally with the result that the glabella is narrowed and ridged at the center.

The specimens of the hypostoma show that it had a large, oval body connected with a narrow neck to a strong, rounded posterior border; the sulcus within the border on each side is sufficiently strong to clearly define the neck connecting the body and posterior border [fig. 9].

A few fragments of thoracic segments occur in association with the cephalons, but nothing to prove more than that the pleuræ had a wide furrow. The test of all the specimens has been destroyed, but the surface of the cephalon, as shown in the fine sandstone matrix, is known to have been marked by a fine, irregular network of very fine, irregular ridges.

Olenellus ? claytoni occurs in an arenaceous shale just above a mass of andesite in the Barrel Spring section [Walcott, 1908*c*, p. 189, 6 of section]. *Olenellus fremonti* and *Salterella* sp. occur in an argillaceous shale at nearly the same horizon, but are not associated with *O. ? claytoni.*

Formation and Locality.—Lower Cambrian: (**1k** and **1i**) " Silver Peak Group," in arenaceous shales interbedded in the lower part of No. 6 of the Barrel Spring section [Walcott, 1908*c*, p. 189], 1.5 and 1.75 miles (2.4 and 2.8 km.) south of Barrel Spring, Silver Peak Quadrangle, Esmeralda County, Nevada.

OLENELLUS FREMONTI, new species

Plate 37, Figs. 1-22; Plate 41, Fig. 8

Olenellus gilberti Walcott (in part) [not Meek], 1884, Monogr. U. S. Geol. Survey, Vol. 8, p. 29, pl. 9, fig. 16a (not fig. 16 and pl. 21, fig 13, referred in this paper to *Callavia nevadensis;* nor pl. 21, fig. 14, referred in this paper to *Olenellus gilberti*). (Described.)

Olenellus howelli Walcott [not Meek], 1884, Monogr. U. S. Geol. Survey, Vol. 8, pp. 30-31, pl. 9, figs. 15, 15a-c; pl. 21, figs. 1-9, and 16-17. (Described and discussed. Figures 15, 15a, 15b, and 15c of plate 9 are copied in this paper, pl. 37, figs. 14, 16, 8, and 6a respectively. Figures 2-9 of pl. 21 are copied in this paper, pl. 37, figs. 10, 12, 11, 15, 13, 17, 19, and 18 respectively.)

Olenellus gilberti WALCOTT (in part) [not MEEK], 1886, Bull. U. S. Geol. Survey, No. 30, pp. 170-180, pl. 18, fig. 1c; pl. 19, figs. 2e, 2h, and 2i; pl. 20 figs. 1, 1a-i, 1k-m; and pl. 21, figs. 2 and 2a (not pl. 18, figs. 1, 1a-b; pl. 19, figs. 2, 2a, 2b, 2k; pl. 20, fig. 4; and pl. 21, figs. 1 and 1a = *Olenellus gilberti;* and not pl. 19, figs. 2c, 2d, 2f, 2g = *Callavia nevadensis*). (Described and discussed. Figures 2e and 2i, pl. 19, are copied in this paper pl. 37, figs. 20 and 6 respectively; fig. 2h, p. 19, is copied from Walcott, 1884, pl. 9, fig. 15c; figs. 1, 1a, and 1b, pl. 20, are copied from Walcott, 1884, pl. 9, figs. 15b, 15a, and 15 respectively; figs. 1c, 1d, 1e, 1g, 1h, 1i, 1k, 1l, and 1m, pl. 20, are copied from Walcott, 1884, pl. 21, figs. 1, 2, 3, 4, 5, 6, 8, 9, and 7 respectively; fig. 1f, pl. 20, is copied in this paper, pl. 37, fig. 9; and the specimen represented by figures 2 and 2a, pl. 21, is copied with slight changes in this paper, pl. 37, fig. 7.)

Olenellus gilberti LESLEY (in part), 1889, Geol. Survey Pennsylvania, Report P4, Vol. 2, p. 490, figs. 2a, and cephalons represented by figs. 1, 1a, 1b, and 1f (not the whole specimen represented by figs. 1 and 1a which is a true *Olenellus gilberti*). (Figure 2a is copied from Walcott, 1886, pl. 21, fig. 2a; figs. 1, 1a, 1b, and 1f are copied from figures of the same number on plate 20 of Walcott's paper [1886].)

Olenellus gilberti WALCOTT (in part) [not MEEK], 1891, Tenth Ann. Rept. U. S. Geol. Survey, pl. 84, figs. 1d and 1f; pl. 85, figs. 1, 1a, and 1f; and pl. 86, figs. 1, 1a-i, 1k-m (not pl. 84, figs. 1, 1a-c; pl. 85, figs. 1b-d; and pl 86, fig. 4 = *Olenellus gilberti;* and not pl. 84, figs. 1e and 1g; and pl. 85, figs. 1e and 1g = *Callavia nevadensis*). (No text reference. Fig 1d, pl. 84, is copied from Walcott, 1886, pl. 18, fig. 1c; figs. 1f, pl. 84, and 1f, pl. 85, are copied from Walcott 1886, pl. 19, figs. 2i and 2e respectively; pl. 86 is a copy of pl. 20 of Walcott's paper [1886]; and figs. 1 and 1a, pl. 85, are copied from Walcott, 1886, pl. 21, figs. 2 and 2a.)

Olenellus gilberti PEACH, 1894, Quart. Journ. Geol. Soc. London, Vol. 50, p. 671, pl. 32, figs. 9 and 10. (Mentioned. Figures 9 and 10 are copied from Walcott, 1886, pl. 20, figs. 1f and 1a.)

Holmia weeksi WALCOTT, 1908, Smithsonian Misc. Coll., Vol. 53, No. 5, p. 187, and p. 189 (6 of section only). (The specimens listed under this name on the pages mentioned are referred in this paper to *Olenellus fremonti.*)

Olenellus fremonti WALCOTT, 1908, Idem, p. 187. (Name given in a list of the species occurring near Resting Springs.)

I formerly referred specimens now included in this species to *Olenellus gilberti* [Walcott, 1884, 1886, and 1891], but with the discovery of additional material, specimens showing variations of such constant character were found that it became necessary to propose a new species to include them.

The cephalon of *O. fremonti* differs from that of *O. gilberti* [pl. 36]: (a) in having a more expanded anterior glabella close to the rounded frontal border; (b) in having a shorter palpebral lobe, both

in the young and the adult; and (c) in having an unusually expanded pleural lobe to the third thoracic segment. A comparison of the young cephalons, as outlined on pl. 37, with those of *O. gilberti,* illustrated on pl. 36, shows some of the differences between the two species.

The variations in the cephalon of *O. fremonti* have been described [Walcott, 1886, pp. 173-178], and reference is also made to them in the introduction to this paper [p. 237].

The species that is most nearly related appears to be *O. thompsoni* [pl. 34], but we find that the latter differs from *O. fremonti* [pl. 37] in having: (a) a space between the glabella and the marginal rim; (b) a less expanded frontal glabellar lobe and longer palpebral lobes; (c) *O. fremonti* also has a peculiarly expanded pleural lobe of the third segment of the thorax [pl. 37, figs. 6, 6*a*].

The same differences exist in relation to *O. lapworthi* [pl. 39]. It differs from *O. logani* [pl. 41] in details mentioned under that species.

Olenellus fremonti is found associated with *O. gilberti* in Nevada at locality No. 30; the two species also occur at locality 1*p,* but not in same layer of rock. Comparisons have been made above with *O. gilberti.*

The hypostoma is very rarely preserved. It is much like that of *O. gilberti* [pl. 36, fig. 5] in having a denticulated posterior margin [pl. 37, figs. 21, 22], and both are much like the hypostoma of *Pædeumias transitans* [pl. 34, figs. 6 and 7].

The outer surface is similar to that of *O. gilberti* and other species of the genus. It is beautifully shown by figs. 4 and 5, pl. 37.

Dimensions.—The largest specimen of the cephalon in the collection has a length of 50 mm., width about 80 mm. This would give an entire dorsal shield, exclusive of the long telson, a length of about 115 mm., which indicates that *O. fremonti* was one of the largest of the Mesonacidæ.

Formation and Locality.—Lower Cambrian: (**30**) arenaceous shales of the Pioche formation, west slope of Highland Range at edge of desert, 8 miles (12.8 km.) north of Bennetts Spring, and about 8 miles (12.8 km.) west of Pioche, Lincoln County; (**313g**) thin-bedded limestones interbedded in shales above a massive series of sandstones, in the Groom Mining District, at the south end of the Timpahute Range, near the line between Nye and Lincoln counties; (**52**) *arenaceous shales above the Prospect Mountain sandstones, summit of Prospect Mountain, Eureka District, Eureka*

County; (51) in thin layers of limestone interbedded between shales and layers of sandstone of the Prospect Mountain formation, west side of summit of Prospect Mountain, Eureka District, Eureka County; and (1p) limestones of No. 2 of the Silver Peak Group, Barrel Spring section [Walcott, 1908*c*, p. 189], about 2.5 miles (4 km.) south of Barrel Spring and .5 mile (.8 km.) east of road, Silver Peak Quadrangle, Esmeralda County; all in Nevada.

(176 and 178a) in arenaceous shales apparently lying between massive limestones carrying *Archæocyathus,* south end of Deep Spring Valley, about 20 miles (32 km.) east-southeast of Big Pine in Owens Valley; (14p) quartzitic sandstones near Resting (Fresh Water) Springs, which is in the southwest corner of T. 21 N., R. 8 E., on the Armagosa River, Inyo County; and (14l) sandstones about 800 feet (244m.) beow massive blue limestones [see Walcott, 1908*c*, p. 187] in pass through Kingston Range, 15 miles (24 km.) east of Resting Springs; all in California.

Fragments of an *Olenellus* with a strong marginal border about the cephalon similar to that of *Olenellus fremonti* occur in (59g) a compact sandstone 2.5 miles (4 km.) west of Siam and 7 miles (11 km.) northeast of Cadiz, on the Atlantic and Pacific Railway, San Bernardino County, California.

OLENELLUS ? GIGAS Peach

PLATE 40, FIG. 1

Olenellus gigas PEACH, 1894, Quart. Journ. Geol. Soc. London, Vol. 50, p. 666, text fig. 1, p. 667. (Described essentially as below. The specimen from which text figure 1 was drawn is reproduced in this paper, pl. 40, fig. 1.)

Of this species only fragments of a large cephalon are known. One of these is illustrated by fig. 1. Of this and several other fragments Dr. Peach tells us that the cephalon is

Much wider compared with its depth than in *O. lapworthi* and *O. reticulatus.* It is further distinguished from the latter by its broad margin and strong genal spine. The ornamentation is readily seen, even with the unaided eye. As stated in the former paper, the pattern of the reticulation is more elongated on the margins and spines than on the general surface, but this applies equally to all the species of *Olenellus.*

Portions of cheeks and genal spines of individuals nearly as large as the above, on which the pattern of the ornamentation is much smaller proportionally to their size, occur in the collection.

Measurements.—Length of head-shield, 52 mm.; breadth of head-shield, 106 mm. = 4½ inches.

A comparison with American specimens of the Mesonacidæ leads me to think that this form may be most nearly related to *Mesonacis vermontana.* With the limited material now available for comparison I will leave it, doubtfully, under *Olenellus.*

FORMATION AND LOCALITY.—Lower Cambrian: argillaceous shale interbedded in " Serpulite grit," a coarse quartzitic sandstone, northern slope of Meal a' Ghubhais 1,200-1,300 feet (366-396 m.) above Loch Maree, 4 miles (6.4 km.) northwest of Kenlochewe in the west of Ross-shire, Scotland.

OLENELLUS GILBERTI Meek

PLATE 36, FIGS. 1-17; PLATE 43, FIGS. 5 AND 6

Olenellus gilberti MEEK, 1874. (Manuscript.)

Olenellus howelli MEEK, 1874. (Manuscript.)

Olenellus gilberti (Meek), WHITE, 1874, Geogr. and Geol. Expl. and Surv. West 100th Meridian, Prelim. Rept., p. 7. (Copies Meek's manuscript description.)

Olenellus howelli (MEEK), WHITE, 1874, Idem, Prelim. Rept., p. 8. (Copies Meek's manuscript description.)

Olenus (*Olenellus*) *gilberti* (Meek), GILBERT, 1875, Idem, Vol. 3, pp. 182-183. (Copied from White, 1874, p. 7.)

Olenus (*Olenellus*) *howelli* (Meek), GILBERT, 1875, Idem, Vol. 3, p. 183. (Copied from White, 1874, p. 8.)

Olenellus gilberti (Meek), WHITE, 1877, Idem, Vol. 4, pt. 1, pp. 44-46, pl. 2, figs. 3a-e. (Described and discussed. The specimens represented by figures 3a, 3b, and 3c are redrawn in this paper, pl. 36, figs. 3, 1, and 2 respectively.)

Olenellus howelli (Meek), WHITE, 1877, Idem, Vol. 4, pt. 1, pp. 47-48, pl. 2, figs. 4a-b. (Described and discussed. The specimen represented by figures 4a-b is redrawn in this paper, pl. 36, figs. 4 and 4a.)

Olenellus gilberti WALCOTT (in part) [not MEEK], 1884, Monogr. U. S. Geol. Survey, Vol. 8, p. 29, pl. 21, fig. 14 (not pl. 9, fig. 16 and pl. 21, fig. 13 referred in this paper to *Callavia nevadensis;* and not pl. 9, fig. 16a, referred in this paper to *Olenellus fremonti*). (Described. Figure 14 is an outline drawing of the specimen figured by White, 1877, pl. 2, fig. 3c, a specimen which is redrawn in this paper, pl. 36, fig. 2.)

Not *Olenellus howelli* WALCOTT, 1884, Idem, pp. 30-31, pl. 9, figs. 15, 15a-c, and pl. 21, figs. 1-9, 16-17. (Referred in this paper to *Olenellus fremonti.*)

Olenellus gilberti (Meek), WALCOTT (in part), 1886, Bull. U. S. Geol. Survey, No. 30, pp. 170-180, pl. 18, figs. 1, 1a-b; pl. 19, figs. 2, 2a, 2b, 2k; pl. 20, fig. 4; and pl. 21, figs. 1 and 1a (not pl. 18, fig. 1c; pl. 19, figs. 2e, 2h, 2i; pl. 20, figs. 1, 1a-i, 1k-m; and pl. 21, figs. 2 and 2a = *Olenellus fremonti;* and not pl. 19, figs. 2c, 2d, 2f, and 2g = *Callavia nevadensis*). (Described and discussed. Figs. 1 and 1a, pl. 18, are copied from White, 1877, pl. 2, figs. 4a and 4b; figs. 2, 2a, 2b, and 2k, pl. 19, are copied

from White, 1877, pl. 2, figs. 3b, 3a, 3c, and 3d respectively; fig. 4, pl. 20, is copied from Walcott, 1884, pl. 21, fig. 14; and pl. 21 is copied in this paper, pl. 36, fig. 9.)

Olenellus gilberti (Meek), HOLM, 1887, Geol. Fören. i Stockholm Förhandl., Bd. 9, Häfte 7, pp. 514-515. (Described in Swedish. The species is frequently mentioned also in the discussion of "*Olenellus kjerulfi*.")

Olenellus gilberti LESLEY (in part), 1889, Geol. Survey Pennsylvania, Report P4, Vol. 2, p. 490, figs. 1 and 1a (not fig. 2a nor the cephalons represented by figs. 1, 1a, 1b, and 1f, these are all referred in this paper to *Olenellus fremonti*). (Figures 1 and 1a are copied from Walcott, 1886, pl. 21, figs. 1 and 1a.)

Olenellus gilberti (Meek), WALCOTT (in part), 1891, Tenth Ann. Rept. U. S. Geol. Survey, pl. 84, figs. 1, 1a-c; pl. 85, figs. 1b-d; and pl. 86, fig. 4 (not pl. 84, figs. 1d and 1f; pl. 85, figs. 1, 1a, and 1f; and pl. 86, figs. 1, 1a-i; 1k-m = *Olenellus fremonti;* and not pl. 84, figs. 1e and 1g; and pl. 85, figs. 1e and 1g = *Callavia nevadensis*). (No text reference. Figs. 1 and 1a, pl. 84, are copied from Walcott, 1886, pl. 21, figs. 1 and 1a; figs. 1b and 1c, pl. 84, are copied from Walcott, 1886, pl. 18, figs. 1 and 1a; figs. 1b-d, pl. 85, are copied from Walcott, 1886, pl. 19, figs. 2, 2a-b, respectively; and fig. 4, pl. 86, is copied from Walcott, 1884, pl. 21, fig. 14.)

Olenellus canadensis WALCOTT (in part), 1908, Canadian Alpine Journal, Vol. 1, No. 2, p. 242. (Name used in list of fossils occurring in a geologic section. The specimens listed include forms now referred to *Olenellus gilberti.*)

Olenellus gilberti Meek, WALCOTT, 1908, Smithsonian Misc. Coll., Vol. 53, No. 5, p. 189. (Species listed in No. 2 of the Barrel Spring section.)

Holmia rowei WALCOTT (in part), 1908, Idem, p. 189 (3 of section only). (The specimens listed under this name from 3 of the Barrel Spring section are referred in this paper to *Olenellus argentus* and *Olenellus gilberti.*)

Olenellus claytoni WALCOTT (in part), 1908, Idem, p. 189. (The specimens listed under this name from 6 of the Barrel Spring section are referred in this paper to *Olenellus claytoni* and *Olenellus gilberti.*)

Olenellus canadensis WALCOTT (in part), 1908, Idem, p. 215. (Name used in section. In both cases, however, the specimens listed include forms now referred to *Olenellus gilberti.*)

Dorsal shield elongate ovate in outline; strongly convex anteriorly when not compressed in the rock. Cephalon of adult semicircular in outline, strongly convex in a granular limestone matrix [figs. 4 and 4*a*], moderately convex in shaly limestone [figs. 16 and 17], nearly flattened and with little convexity in siliceous shales [figs. 1, 2, and 3]; bordered by a rounded marginal rim that is extended into somewhat slender genal spines; the posterior marginal border is rounded and narrow, and, in most specimens, it has a thickened

intergenal angle beyond which it becomes more narrow and extends more or less obliquely forward to join the outer border [figs. 1, 2, 3, and 4]; in one example a short intergenal spine occurs [fig. 8]; a rounded, well-defined, shallow furrow separates the marginal border from the cheeks. The plane of the marginal border is slightly and broadly arched across the front, the arching or rising of the border beginning opposite the longitudinal center of the eye lobe.

Glabella elongate with sides nearly parallel to the point of attachment of the palpebral ridge to the slightly expanded anterior glabellar lobe; the glabella is convex and elevated above the level of the palpebral lobes; the anterior lobe arches down to the level of the frontal marginal rim and terminates at about the width of the marginal border from the inner edge of the border; the second and third lobes of the glabella are narrow and united across their ends as the furrow separating them does not extend to the dorsal furrow alongside the glabella; the fourth lobe is wider than the second and third, and of about the same width as the occipital furrow; the slightly oblique transverse furrows are united across the center by a very shallow transverse furrow; they terminate laterally at the dorsal furrow with the exception of the second pair, which in large specimens of the cephalon may be little more than transversely elongated pits [fig. 16]. Occipital ring strong and clearly defined; it is convex, with the exception of a depressed area extending from the base of the median spine outward to the end of the ring; the effect of this in flattened specimens is to give rise to what appears to be a division of the ring transversely into two parts; a small, elongate median node or short spine occurs near the posterior margin of the ring [fig. 3].

The anterior flattened rim of the palpebral lobe is joined to the postero-lateral base of the anterior lobe of the glabella, from which it arches back to opposite the center of the occipital ring, where it is about its own width from the dorsal furrow beside the glabella: its width is nearly that of the second and third transverse lobes of the glabella; the elongate central area of the palpebral lobe is slightly convex and depressed beneath the level of the outer rim; the visual surface of the eye is elongate and narrow, it rises abruptly from its base with a gentle outward curvature or bulging to the outer rim of the palpebral lobe. The openings of the corneal lenses of the eye appear to be circular when viewed with a half-inch Bausch and Lomb aplanatic triplet lens, but when photographed and enlarged to seventy-five diameters they have an hexagonal outline [pl. 43,

fig. 5], in this respect being similar to those of *Limulus* [pl. 43, figs. 1-4]. The lenses, as seen in one specimen, are arranged in quincunx order, the rows crossing the visual surface of the eye obliquely between the upper and lower margins. The narrow ridges between the lenses are rounded and have the same exterior appearance as the outer surface of the eye of *Limulus polyphemus*. The cheeks rise rather abruptly from the rounded intermarginal furrow and gently arch to the base of the eye and first glabellar lobe. A narrow, elevated line or ridge extends outward from the posterior base of the eye and crosses the posterior border obliquely so as to terminate at the intergenal angle or is continued into a short spine. This ridge follows the line of the facial suture which is probably in a condition of symphysis; no traces of the facial suture have been observed in front of the eye.

The only specimens preserving the thorax are flattened in shaly sandstone. The one illustrated has been compressed and distorted [fig. 9], but it shows the general form of the thorax and its segments. Fourteen segments and the base of the telson-like terminal spine can be determined. The axial lobe is convex and about one-half the width of the pleural lobes; a very short median spine, or sharp, elongate node, occurs at the posterior margin of each segment with its rather strong base reaching nearly half way across the segment; the pleural portions of each segment extend directly outward for a distance about one-half of their length and then curve gradually backward, passing into a slender, spine-like extension: the pleural furrow is broad and of nearly equal width from its inner end out to the geniculation of the pleura where it begins to narrow. The enlargement of the third segment is the same as in *Olenellus thompsoni* [pl. 35] and *Pædeumias* [pl. 34]. The telson is long and slender, and much like that of *O. fremonti* [pl. 37, fig. 7] and *Olenellus thompsoni* [pl. 34, fig. 9].

Surface ornamented with irregular, fine, inosculating ridges that form a very fine network of varying pattern. On the border and cheeks the meshes are small, elongated, and subparallel to the margin: over the glabella the meshes are very fine and the same is true for the surface of the thorax; the interspaces between the ridges appear to be minutely granular. The inner surface of the cheeks is beautifully channelled by irregular canals that radiate from the base of the eye outward toward the intermarginal groove; the channels often run into each other, and they are frequently united by cross channels.

Dimensions.—The largest cephalon has a length of 41 mm., width 60 mm., convexity 13 mm. [figs. 4 and 5]. The only specimen of the thorax is too much distorted to base measurements upon it.

Young stages of growth.—Some of the younger stages of growth of the cephalon are beautifully preserved in a compact, dark limestone from Ptarmigan Pass (locality No. 35l). A few are illustrated. These show that in the cephalons from 2 to 6 mm. in length there is considerable variation in outline. The smallest have a subquadrilateral outline with a distinct antero-lateral angle and short spine [figs. 11-13]. As the cephalon increases in size the angle and spine disappear, and the evenly rounded outline is unbroken from the genal angles to the broadly rounded front margin [figs. 15-17]. The palpebral lobes of the smallest cephalon, 1.75 mm. in length, terminate posteriorly opposite the third glabellar furrow [fig. 11], and this continues up to specimens 15 mm. in length [fig. 15], but in the large cephalons 20 to 40 mm. in length the palpebral lobe is proportionally larger and ends at the furrow within the posterior margin of the cephalon [figs. 1-4, 16 and 17]. The space between the frontal lobe of the glabella and the anterior wire-like border of the cephalon varies slightly, but it is rarely that it is narrower than the width of the frontal border. The intergenal spines [figs. 11-14] are the continuation of the ridge running from the base of the eye that appears to represent the line of the facial suture back of the eye; the antero-lateral spines are in the position where I should anticipate finding the termination of the facial suture, in front of the eye. The comparison of the young stages of growth of this species with similar known stages in other species is made in the introduction [pp. 236-243].

An hypostoma occurring (locality No. 1h) with specimens of the cephalon of this species has a denticulated posterior margin much like that of the hypostoma of *Wanneria halli* [pl. 31, fig. 9], and *Olenellus fremonti* [pl. 37, figs. 21, 22]. It is strange that there are almost no traces of the hypostoma in association with the large number of specimens of the cephalon that occur at many localities, both in Nevada and Alberta. The hypostoma of *O. canadensis* is unusually abundant in association with that species and *O. gilberti*.

Observations.—In my earlier work [Walcott, 1884, 1886, and 1891] I gave a large variation to this species, and included in it forms that are now grouped under *Callavia nevadensis* and *Olenellus fremonti*. As now restricted, *O. gilberti* includes forms that have

a wide geographic distribution in the Cordilleran area of the United States and Canada, and a possible stratigraphic range of several hundred feet in the upper portion of the Lower Cambrian (Georgian) formations. Its representative on the eastern side of the continent in the Appalachian area is *Olenellus thompsoni* [pl. 34], and in Scotland *O. lapworthi* [pl. 39]. In Canada a form that I have identified with this species occurs in the Mount Whyte formation at several localities, the most prolific of which is at Ptarmigan Pass, Alberta (locality No. 35l), where a number of small and large cephalons were found in a thin layer of limestone at the base of an argillaceous shale. Fragments of *O. canadensis* are also abundant in this limestone and in the arenaceous beds beneath. Another notable locality is near the base of the Mount Stephen section (locality No. 35f), about 300 feet below the summit of the Lower Cambrian.

Comparison with other species of *Olenellus* shows that *O. gilberti* differs from *O. fremonti* [pl. 37]: (a) in having its glabella separated from the frontal border by a clear space; (b) in having a longer, larger palpebral lobe and eye; (c) in having the third thoracic segment very little, if any, larger than the fourth and fifth; (d) in having the pleural lobes proportionally wider. The two species are associated in eastern (locality no. 30) and western Nevada (locality no. 1p).

From *O. thompsoni* it differs in the less expanded anterior lobe of the glabella and the space in front of the lobe.

From *O. lapworthi* [pl. 39, figs. 1-8] it differs in many minor details and most notably in the form of the thorax and thoracic segments.

The most nearly related cephalon is that of *Pædeumias transitans* [pl. 34], and the thorax of the two species is very similar back to the large spine. If *O. gilberti* should be found to have rudimentary segments and pygidium posterior to its telson-like spine the two forms would probably be placed under the species *gilberti* of the genus *Pædeumias*.

Formation and Locality.—Lower Cambrian: (31a) *in dark, fine, arenaceous shales and interbedded thin layers of limestone in the Pioche formation, on both the east and west slopes of the anticline of quartzitic sandstone at the mining camp of Pioche;* and (30) west slope of Highland Range 8 miles (12.8 km.) north of Bennetts Spring and about 8 miles (12.8 km.) west of Pioche; both in Lincoln County, Nevada.

(**1m** and **1p**) limestones of No. 2 of the Silver Peak Group, Barrel Spring section [Walcott, 1908*c*, p. 189], about 2.5 miles (4 km.) south of Barrel Spring,[1] and .5 mile (.8 km.) east of the road; (**1l**) same locality as No. **1m**, in the shales of No. 3 of the Barrel Spring section [Walcott, 1908*c*, p. 189]; (**1i**) 1.5 miles (2.4 km.) south of Barrel Spring in No. 6 of the Barrel Spring section [Walcott, 1908*c*, p. 189]; (**1o**) same horizon as No. **1l**, 3 miles (4.8 km.) southeast of Barrel Spring; (**1y**) fine, arenaceous shales in small buttes in Clayton Valley, about 3 miles (4.8 km.) southeast of Silver Peak; and (**16g**) fine, arenaceous shale at the Paymaster Mining Camp, .25 mile (.4 km.) west of Esmeralda; all in Esmeralda County, Nevada.

(**30a′**) thin-bedded limestone on the north side of Big Cottonwood Canyon, 1 mile (1.6 km.) below Argenta, southeast of Salt Lake City, Utah.

(**60c**) calcareous sandstones of the upper 20 feet of the St. Piran formation; and (**35l**) limestone layer above the arenaceous beds of No. 60c, and below an argillaceous shale; both on the south slope of Ptarmigan Pass, near the head of Corral Creek, 9 miles (14.4 km.) northeast of Laggan, Alberta.

(**35e**) about 270 feet (83 m.) below the top of the Lower Cambrian in greenish, siliceous shales (64 feet) forming 2c of the field section in the amphitheater between Popes Peak and Mt. Whyte, 3 miles northwest of Lake Louise, which is southeast of Laggan, Alberta.

(**35h**) about 375 feet (114 m.) below the top of the Lower Cambrian in the shales of No. 4 of the Mount Whyte formation [Walcott, 1908*c*, pp. 214-215], on Mount Bosworth, north of the Canadian Pacific Railway between Hector and Stephen; (**35f**) about 300 feet (91 m.) below the top of the Lower Cambrian in the limestone forming 6 of the Mount Whyte formation [Walcott, 1908*b*, p. 242], just above the old tunnel on the north shoulder of Mt. Stephen, 3 miles (4.8 km.) east of Field; and (**57i**) about 175 feet (53 m.) below the top of the Lower Cambrian in the beds forming 4 of the Mount Whyte formation [Walcott, 1908*b*, p. 241] at the same locality as No. 35f; all in British Columbia.

[1] Barrel Spring is about 10 miles (16 km.) south of the town of Silver Peak in the Silver Peak Quadrangle.

OLENELLUS GILBERTI, var.

PLATE 40, FIG. 8

This small cephalon 3.5 mm. in length occurs in association with *Olenellus canadensis* [pl. 38] and *O. gilberti* [pl. 36]. Its large eye and broad space between the marginal rim and glabella distinguish it at once from *O. canadensis,* and its stronger marginal rim and very strong ridge connecting the anterior lobe of the glabella with the elevated eye lobe distinguish it from cephalons of the same size referred to *O. gilberti.* It is unlike the latter, but it has so many points in common with it that I will designate it as *O. gilberti* var.

FORMATION AND LOCALITY.—Lower Cambrian: Mount Whyte formation: (35l) limestone layer above the arenaceous beds of the St. Piran formation and below an arenaceous shale, on the south slope of Ptarmigan Pass, near head of Corral Creek, 9 miles (14.4 km.) north-northeast of Laggan, Alberta, Canada.

OLENELLUS LAPWORTHI Peach

PLATE 39, FIGS. 1-7; AND PLATE 40, PART OF FIG. 3

Olenellus lapworthi PEACH and HORNE, 1892, Quart. Journ. Geol. Soc. London, Vol. 48, pp. 236-241, pl. 5, figs. 1-11. (Described and discussed.)

Olenellus lapworthi Peach and Horne, PEACH, 1894, Quart. Journ. Geol. Soc. London, Vol. 50, pp. 662-664, pl. 29, figs. 1, 2, and 2a; pl. 30, fig. 7; pl. 32, fig. 8. (Described and discussed.)

Olenellus lapworthi elongatus PEACH, 1894, Idem, p. 664, pl. 29, figs. 3-6. (Characterized as a new variety. The specimen represented by figure 3, pl. 29, is redrawn in this paper, pl. 39, fig. 1.)

Olenellus intermedius PEACH, 1894, Quart. Journ. Geol. Soc. London, Vol. 50, pp. 666-668, pl. 32, fig. 7. (Described and illustrated.)

Olenellus lapworthi belongs to that group of the Mesonacidæ represented by *O. thompsoni* [pl. 35], *O. gilberti* [pl. 36], and *O. fremonti* [pl. 37]. Its relation to the adult of *O. thompsoni* may be seen by comparing figs. 2-4, pl. 39, with fig. 9, pl. 34. A young stage of *O. lapworthi* [pl. 39, fig. 8] may be compared with a young specimen of *Pædeumias transitans* [pl. 32]. Also compare the hypostoma [fig. 7, pl. 39] with that represented by fig. 7, pl. 34.

Olenellus lapworthi differs from *O. thompsoni:* (a) in having a shorter eye lobe that extends more obliquely outward; and (b) in the geniculation of the pleuræ of the thoracic segments which is more abrupt [compare fig. 2, pl. 39, with fig. 1, pl. 35]. The eye

lobe of *O. lapworthi* is much like that of *O. fremonti* [pl. 37, fig. 2], but the relative position of the glabella and frontal border of the cephalon is different, as also the enlarged third segment. *O. gilberti* [pl. 36] has a larger eye lobe than *O. lapworthi,* but in other respects the two species are very closely related. It is also interesting to note that *O. intermedius* Peach [1894, pl. 32, fig. 7], a form that I think is the young of *O. lapworthi,* has antero-lateral angles on the cephalon not unlike similar angles on the young cephalons of *O. gilberti* [pl. 36, figs. 11-14].

In the synonomy of *O. lapworthi* I have included *O. intermedius* Peach and *O. lapworthi elongatus* Peach. The first I regard as a young cephalon preserving the antero-lateral angles that subsequently disappear, and the advanced genal angles and small eyes that are so well shown by the young of *O. fremonti* [pl. 37, figs. 11-12]. The variety *elongatus* appears from the specimens to be the result of elongation by slight distortion in the shales.

A cephalon 26 mm. in length has a width of 44 mm. All of the illustrations on pl. 39 are from photographs of compressed specimens in a fine argillaceous shale.

The hypostoma [pl. 39, fig. 7] is much like that of *Pædeumias transitans* [pl. 34, figs. 5-7] in having an ovate body and denticulated posterior and postero-lateral margins. I found one quite young cephalon in the material of the Geological Survey of Scotland [fig. 6] 1.5 mm. in length that shows prolonged intergenal spines, elongated eye lobes, and segmented palpebral lobes, not unlike those of *Elliptocephala asaphoides* [pl. 25, figs. 9-10].

The surface of the cephalon and thorax is marked by a rather strong network of fine, slightly elevated ridges of the same character as those on *O. reticulatus* [pl. 39, figs. 10, 11], except that the network and ridges are finer.

O. lapworthi differs from the associated *O. reticulatus* in its larger eye lobe, more finely reticulated surface and minor details mentioned under the latter species. It is the representative on the eastern side of the Atlantic basin of *O. thompsoni* of the St. Lawrence province of the western side of the Atlantic. The closely allied *O. gilberti* is from the Cordilleran trough of western America.

Formation and Locality.—Lower Cambrian: argillaceous shale interbedded in "Serpulite grit," a coarse, quartzitic sandstone, northern slope of Meal a' Ghubhais, 1,200-1,300 (366-396 m.) above Loch Maree, 4 miles (6.4 km.) northwest of Kenlochewe in the west of Ross-shire, Scotland.

OLENELLUS LOGANI, new species

PLATE 41, FIGS. 5, 6

Cephalon transversely semicircular in outline with the marginal border at the genal angles prolonged into slender spines; strongly convex with the eye lobes and front lobe of the glabella rising abruptly from the cheeks and frontal marginal border; marginal border very distinctly rounded, strong, and arching up slightly in front of the glabella from the plane of the lower edge of the cephalon; at the genal angles it merges into the genal spine and the narrow, rounded posterior marginal border of the cephalon; the latter border is crossed obliquely by a low, slender ridge that is extended beyond the border as a short intergenal spine.

Glabella with a convex, expanded anterior lobe that rises abruptly from just within the front marginal border; in a small specimen 4.5 mm. in length there is a narrow space between the border and the glabella; the glabella is divided into four lobes and the occipital ring by four pairs of furrows that extend obliquely inward and backward from the dorsal furrow on each side to the median line, where they unite, except in the case of the anterior pair which fade out just before reaching the median line; the second pair of furrows curve backward at their outer end so as to arch nearly around the ends of the third glabellar lobe; the anterior lobe is as long as the three narrow lobes combined and a little wider than long; it is connected at its postero-lateral margin, on each side, with the palpebral lobes by strong, rounded ridges that are a little depressed at the dorsal furrow; a faint furrow extends inward on each side a short distance from the point where the anterior margin of the palpebral ridges joins the anterior glabellar lobe; this pair of furrows indicates that the lobe is formed of two segments of the original primitive cephalon.[1] The palpebral segment is beautifully shown by the young of *Elliptocephala asaphoides* [pl. 25, figs. 9 and 10]. The second glabellar lobe is narrow and arched slightly backward at each end so as to nearly enclose the ends of the third lobe, which is thus shortened as compared with the second and fourth lobes; the third lobe is cut off by the arching of the second, but the fourth lobe extends out to the dorsal furrow where, with a very slight interruption, it crosses the line of the dorsal furrow and merges into the space within the palpebral lobe; the third and fourth lobes are

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[1] This anterior pair of furrows is shown for *Paradoxides* by Barrande's illustrations of *P. spinosus* [Barrande, 1852, pl. 12, figs. 2, 3, and 6; pl. 13, fig. 1] and *P. pusillus* [Barrande, 1872, pl. 9, fig. 23].

a little larger longitudinally than the second lobe; the second, third, and fourth lobes all arch backward at the center where they are most convex and rounded so as to give the impression of a longitudinal ridge extending from the base of the first lobe backward and across the occipital ring, where it terminates in a minute node; the extensions of the second and fourth lobes into the interpalpebral lobe space suggest the primitive segmentation of the cephalon, as shown in the young of *Elliptocephala asaphoides* [pl. 25, figs. 9 and 10], and *Pædeumias transitans* [pl. 25, fig. 22]. On the largest cephalon, 11 mm. in length, there is a faint, shallow, narrow groove on each side in advance of the palpebral ridge just within the base of the anterior glabellar lobe that outlines a very narrow ridge somewhat similar to that of *Callavia crosbyi* [pl. 28, fig. 1], except that it is not as clearly defined. Occipital ring rounded, prominent, arched a little backward, and with a minute, median, sharp node on a longitudinally elongated base.

Palpebral lobes narrow, slightly rounded, gently curved, connected to the first glabellar lobe by a rounded ridge and terminating posteriorly opposite the ends of the fourth pair of glabellar furrows at about the width of the palpebral lobe from the dorsal furrows beside the glabella; the lobes rise to nearly the level of the median line of the glabella and cap the visual surface of the eye, which rises abruptly from the cheeks; interpalpebral space depressed and separated from the third and fourth lobes of the glabella by a very faint dorsal furrow; visual surface of eye narrow and arching beneath the outer edges of the palpebral lobe. Cheeks of medium width and rising rather abruptly from the intermarginal furrow to the base of the eye; nothing can be seen on the outer surface indicating a facial suture, but the cast of the inner surface shows a narrow ridge extending from the posterior end of the eye outward and backward so as to cross the marginal border at about two-thirds of the distance from the occipital ring to the genal angle.

Surface beautifully ornamented by a fine network of very narrow, slightly elevated ridges; on the marginal border the meshes of the network are elongated subparallel to the border; on the large first lobe of the glabella the long axes of the meshes curve around subparallel to the anterior margin of the lobe; over the remaining portions of the surface no marked direction is noted as the meshes are irregular in form and arrangement; the inner surface of the checks shows the cast of a system of irregular channels extending outward from the base of the eye toward the intermarginal groove.

Dimensions.—The largest cephalon has a length of 11 mm., width 20 mm. The proportions of the various parts are shown in the photograph of an entire cephalon illustrated by fig. 5, pl. 41.

Observations.—*O. logani* is the Atlantic Province representative of *O. fremonti* [pl. 37] of the southern Pacific Province area. It differs from *O. fremonti* in minor details of the glabella, especially the furrow and smaller lobes, in its proportionally larger eyes, and in the regular form of its genal angles. It has larger eyes than *O. canadensis* [pl. 38].

FORMATION AND LOCALITY.—Lower Cambrian: L'Anse au Loup limestone at L'Anse au Loup, Labrador, on the Straits of Belle Isle, Canada.

Type specimens in the Museum of the Geological Survey of Canada.

OLENELLUS RETICULATUS Peach

PLATE 39, FIGS. 9-13

Olenellus reticulatus PEACH, 1894, Quart. Journ. Geol. Soc. London, Vol. 50, pp. 665-666, text fig. A, p. 673, pl. 30, figs. 1-6, 8-14; pl. 31, figs. 1-7. (Described and illustrated, most of the description being copied below. The specimens represented by figures 1 and 2 of plate 30 are redrawn in this paper, pl. 39, figs. 9 and 10.)

Dr. Peach, in comparing this species with its most nearly related form, *O. lapworthi,* says, after stating that it is of larger size:

The reticulated ornament on its test appears to be much larger in pattern (compared with its size) than in that species, and this difference, which makes it conspicuously visible to the naked eye, has suggested the specific name which I propose for the new form. In general aspect it much resembles the elongated variety of *O. lapworthi.* It differs from that chiefly in the head-shield, which is deeper in comparison with its breadth. The glabella is longer in proportion to the size of the head-shield, and the individual lobes are each more elongated, while the angles made by the furrows with the general axis of the body are more acute. The distal ends of the eye lobes are not so far removed from the edge of the glabella, nor do they extend so far backwards, but end well in front of the fourth furrow, while those of *O. lapworthi* extend beyond it. The raised margin that bounds the cheeks is not so wide in proportion; the genal spine is more slender, and is placed a little more anteriorly, and the notch between it and the pleural angle is deeper than in *O. lapworthi.*

The arrangement of the details of its body-segments is similar to that of *O. lapworthi,* but the peculiarities of the pleura of the third segment are even more pronounced, the spines being longer relatively, and sometimes more incurved. The spines on the pleura of the sixth and three succeeding segments are longer and more slender. Tubercles have been observed in the mid-line on the occipital ring, on the axes of the first three free segments, and on several of the posterior

ones. They have not been observed on all the intermediate segments, but this may be owing to bad preservation or faulty observation, as it is probable that they once existed.

The telson is long and styliform, and tapers rapidly at first and then decreasingly. Its articulation with the last free segment is well shown in the specimen from which pl. 30, fig. 12, was taken. Projecting from the posterior margin of the axis of the fourteenth free segment, at about 1-5 of its width from each side, are two small protuberances. Corresponding projections proceed forwards from the hinge-line of the telson, and interlock with them on their outside. Beyond them the anterior edge of the telson is continued in nearly the same line with the hinge, so that the anterior angles of the telson appear to be overlapped by the pleura of the last free segment. A "lock joint" is thus formed which does not allow of the telson folding downward beyond a certain angle with the plane of the last segment.

The most marked and to me important point of difference with *O. lapworthi* is the much smaller eye. This is best seen by comparing fig. 12 with fig. 1 on pl. 39. The eye of *O. reticulatus* is like that of *O. canadensis* [pl. 38, figs. 4, 5, 6], and in both species we find a tubercle between the posterior end of the eye lobe and the glabella.

Formation and Locality.—Lower Cambrian: argillaceous shale interbedded in "Serpulite grit," a coarse quartzitic sandstone, northern slope of Meal a' Ghubhais, 1,200-1,300 feet (366-396 m.) above Loch Maree, 4 miles (6.4 km.) northwest of Kenlochewe in the west of Ross-shire, Scotland.

OLENELLUS THOMPSONI (Hall)

Plate 34, Fig. 9; Plate 35, Figs. 1-7

Olenus thompsoni Hall, 1859, Twelfth Ann. Rept. New York State Cab. Nat. Hist., p. 59, fig. 1, p. 60. (Described as a new species.)

Olenus thompsoni Hall, 1859, Nat. Hist. New York, Paleontology, Vol. 3, pt. 1, pp. 525-526, text figure, p. 526. (Copy of the preceding reference.)

Barrandia thompsoni Hall, 1860, Thirteenth Ann. Rept. New York State Cab. Nat. Hist., pp. 115-116, text figure, p. 116. (Described, beginning with the 5th paragraph under "Genus Barrandia.")

Paradoxides asaphoides Emmons, 1860, Manual of Geology, 2d ed., p. 87. (Name used in legend of fig. 70, p. 87, see following reference.)

Paradoxides macrocephalus Emmons, 1860, Idem, p. 88, fig. 70. (In the text reference on page 87 this figure is referred to as *Paradoxides asaphoides;* but from the figure there is little doubt that it was taken from a specimen of *O. thompsoni*. In the first edition of the Manual of Geology the figure is labeled *Paradoxides brachycephalus*. On page 280 there is a note on the stratigraphic position of the species.)

Eliptocephalus (*Paradoxides*) *asaphoides* EMMONS, 1860, Idem, p. 280. (Note on the stratigraphic position of the species.)

Paradoxides thompsoni (Hall), EMMONS, 1860, Idem, p. 280, note A. (Note on the stratigraphic position of the species.)

Paradoxides thompsoni (Hall), BARRANDE, 1861, Bull. Soc. Géol. de France. 2d ser., Vol. 18, p. 276, pl. 5, fig. 6. (Translates into French the description given by Hall, 1859, p. 59. Figure 6 is copied from Hall's figure [1859, fig. 1, p. 60].)

Paradoxides macrocephalus Emmons, BARRANDE, 1861, Idem, pp. 276-277, pl. 5, fig. 7. (Discussed in French. Figure 7 is copied from Emmons, 1860, fig. 70, p. 88.)

Not *Paradoxides thompsoni* BILLINGS, 1861, Geol. Survey Canada, Paleozoic Fossils, p. 11. (Referred in this paper to *Pædeumias transitans,* see page 305.)

Barrandia thompsoni HALL, 1861, Report on the Geology of Vermont, Vol. 1, pp. 369-370. (Copy of Hall, 1860, pp. 115-116.)

Barrandia thompsoni HALL, 1862, Report on the Geology of Vermont, Vol. 2, pl. 13, fig. 1. (Copied from Hall, 1860, text figure, p. 116.)

Olenellus thompsoni HALL, 1862, Fifteenth Ann. Rept. New York State Cab. Nat. Hist., p. 114. (Generic name *Olenellus* proposed for this species, *Barrandia* being preoccupied.)

Not *Olenellus thompsoni* BILLINGS, 1865, Geol. Survey Canada, Paleozoic Fossils, Vol. 1, p. 11. (Reprinted from Billings, 1861a, p. 11, substituting *Olenellus* for *Paradoxides,* but the species is referred in this paper to *Pædeumias transitans.*)

Olenellus thompsoni (Hall), FORD, 1881, American Journ. Sci., 3d ser., Vol. 22, fig. 12, p. 258. (Figure 12 is copied from Hall, 1860, text figure on page 116.)

Not *Olenellus thompsoni* WHITFIELD, 1884, Bull. American Mus. Nat. Hist., Vol. 1, No. 5, pp. 151-153, pl. 15, fig. 1. (Referred in this paper to *Pædeumias transitans.*)

Olenellus thompsoni (Hall), WALCOTT (in part), 1886, Bull. U. S. Geol. Survey No. 30, pp. 167-168, pl. 17, figs. 2, 4 and 9; pl. 22, fig. 1, and pl. 23, fig. 1. (not fig. 1, pl. 17 referred in this paper to *Olenellus thompsoni crassimarginatus*). (Copies the original description given by Hall [1859, p. 59] and discusses species. Figure 2, pl. 17, is redrawn in this paper, pl. 34, fig. 9; fig. 9, pl. 17, is a restored drawing of the specimen which is figured in this paper, pl. 35, fig. 4; and fig. 1, pl. 23, is copied with slight alterations in figure 1 of plate 35 of this paper.)

Olenellus thompsoni (Hall), HOLM, 1887, Geol. Fören. i Stockholm Förhandl., Bd. 9, Häfte 7, p. 514. (Described in Swedish. The species is frequently mentioned also in the discussion of "*Olenellus kjerulfi.*")

Elliptocephala thompsoni (Hall), MILLER, 1889, North American Geology and Paleontology, p. 546, text fig. 1003. (Figure 1003 is copied from Walcott, 1886, pl. 17, fig. 2.)

Olenellus thompsoni, LESLEY, 1889, Geol. Survey Pennsylvania, Rept. P4, Vol. 2, p. 491, 3 text figures. (The large figure is copied from Walcott, 1886, pl. 22, fig. 1; figures 2 and 9 are copied from Walcott, 1886, pl. 17, figs. 2 and 9.)

Olenellus thompsoni (Hall), WALCOTT (in part), 1891, Tenth Ann. Rept. U. S. Geol. Survey, pl. 82, figs. 1 and 1a; pl. 83, figs. 1 and 1a (not fig. 1b, pl. 83, which is referred in this paper to *Olenellus thompsoni crassimarginatus*). (No text reference. Figures 1 and 1a, pl. 82, and 1 and 1a, pl. 83, are copied from Walcott, 1886, pl. 23, fig. 1; pl. 17, fig. 9; pl. 22, fig. 1; and pl. 17, fig. 2, respectively.

Olenellus thompsoni (Hall), COLE, 1892, Natural Science, Vol. 1, fig. 1, p. 343. (Gives diagrammatic outline of Walcott's figure, 1886, pl. 17, fig. 2.)

Olenellus thompsoni (Hall), FRECH, 1897, additional plates inserted in 1897 in Lethæa geognostica, pt. 1, Lethæa Paleozoica, Atlas, pl. 1a, fig. 7. (Figure 7 is copied from Walcott, 1886, pl. 23, fig. 1.)

Olenellus thompsoni (Hall), MOBERG, 1899, Geol. Fören. i Stockholm Förhandl., Bd. 21, Häfte 4, pp. 314 and 317, pl. 13, fig. 2. (Mentioned at several places in the text. The figure is copied from Walcott, 1886, pl. 17, fig. 2.)

Olenellus thompsoni (Hall), LINDSTRÖM, 1901, Kongl. Svenska Vet.-Akad. Handlingar, Vol. 34, No. 8, p. 12. (Merely refers to species in discussion of " facial ridge.")

The adult form of *Olenellus thompsoni* Hall has been described and illustrated [see Walcott, 1886, p. 167; also 1891, p. 635], but with the discovery of *Pædeumias transitans* [pls. 32, 33, and 34] a limitation of the variation in the cephalon has been found that may be of service in identifying the species in the future. The illustration accompanying the original descriptions of *Olenus thompsoni* [Hall, 1859, p. 60, fig. 1] shows a cephalon with strong marginal rim, elongate eyes, and with anterior lobe of the glabella terminating in front at the marginal border, as in our fig. 9, pl. 34. I find in the collections from the locality at Parkers quarry, where the specimen described and illustrated by Hall came from, a number of finely preserved specimens in which the anterior lobe touches the anterior border, as in fig. 9, pl. 34, and in the illustration by Hall. On the cephalon of *Pædeumias transitans* the glabella is separated from the marginal border by a distinct space [pls. 32, 33, and 34], except in fig. 1, pl. 33, where the glabella is crushed down nearly to the border. This distinction between the cephalon of *O. thompsoni* and *Pædeumias transitans* is found in specimens from Vermont, Pennsylvania, Tennessee, and Alabama. It is quite probable that the separated cephalons of *Mesonacis vermontana* [pl. 26, fig. 1] may be taken for those of *O. thompsoni* when the thorax is broken away, but this is not of serious importance as the two species are associated both in Vermont and Pennsylvania.

The hypostoma of the adult is very rarely preserved at the Georgia, Vermont, localities. In one example [pl. 35, fig. 3] the bases of

three spines are indicated along the postero-lateral margin. It is quite probable that the hypostoma was similar to that represented by fig. 7, pl. 34.

Comparison with other species.—The most nearly related species to *O. thompsoni* [pl. 34, fig. 9] is *O. fremonti* [pl. 37, figs. 1 to 7]. The most marked difference between them is in the larger frontal lobe of the glabella and smaller eye lobe of *O. fremonti.* The cephalon of the latter also has a much greater variation in outline resulting from the position of the genal angles. From *Pædeumias transitans* [pls. 32 and 34] it differs in having the glabella close to the front marginal border, and in the absence of the rudimentary segments and pygidium posterior to the fifteenth segment, parts which are represented in *O. thompsoni* by a strong, long telson. From *O. gilberti* [pl. 36] it differs in the cephalon in the same manner as from *P. transitans.*

Distribution.—Numerous specimens of the cephalon have been collected from the limestone on the north shore of the Straits of Belle Isle, Labrador; on the west coast of Newfoundland at Bonne Bay; along the St. Lawrence Valley from Bic to the Island of Orleans, near Quebec; on the east side of the Champlain Valley, Franklin County, Vermont; in central Pennsylvania; and from thence to central Alabama.

Dimensions.— The proportions of the various parts of the dorsal shield are clearly shown by the figures on pls. 34 and 35. The larger fragments found indicate a dorsal shield 150 to 160 mm. in length. The average size of adults is from 60 to 100 mm. in length, including terminal telson.

FORMATION AND LOCALITY.—Upper part of Lower Cambrian: (**25**) *in the argillaceous shales of Parkers quarry, near Georgia;* (**25a**) 2 miles east of Swanton, on the Donaldson farm; and I noted its presence west of St. Albans, in the outskirts of the city; in the massive magnesian limestones, west of Parkers quarry, and also about 1.5 miles (2.4 km.) east of the hotel at Highgate Springs; all in Franklin County, Vermont.

This species occurs in the conglomerate limestones of Bic Harbor, Trois Pistoles, St. Simon, and on the Island of Orleans, in the St. Lawrence River, below Quebec, Canada [Walcott, 1886, p. 26].

(**49d**) 3 miles (4.8 km.) east of Waynesboro, Franklin County; (**49f**) Mt. Holly quartzite at Mt. Holly Gap. South Mountain[1]; (**8q**) argillaceous shales and limestone, 3 miles (4.8 km.) northwest

[1] See also Walcott, 1896, pp. 24-26.

of the city of York; (**49c**) just north of the railway station at Emigsville, York County; (**49b**) 2 miles (3.2 km.) northwest of Emigsville in continuation of the ridge from which No. 49c was collected; (**49e**) 1 mile (1.6 km.) south of Mt. Zion Church and 4 miles (6.4 km.) northeast of York; and (**12w**) just west of Fruitville, about 2 miles (3.2 km.) north of the city of Lancaster and westward at various localities to the Susquehanna River, notably 1 mile (1.6 km.) north of Rohrerstown on farm of Noah L. Getz, Lancaster County; all in Pennsylvania.

(**47d**) 1 mile (1.6 km.) east-southeast of Smithsburgh; (**47e**) 2 miles (3.2 km.) south of Keedysville, on Observatory Hill; and (**47f**) at Eakles Mill, 2 miles (3.2 km.) south of Keedysville; all in Washington County, Maryland.

(**47**) in a hard sandstone .75 mile (1.2 km.) up a little brook opposite Gilmore on the south side of the Shenandoah River; (**47g**) shaly sandstone on Mason Creek 1 mile (1.6 km.) east of Salem; and (**47c**) on the south side of the Potomac River, 2 miles (3.2 km.) west of Harpers Ferry bridge; all in Virginia.

(**46**) at the western base of the ridge of Knox sandstone [Safford] 5.5 miles (8.8 km.) west of Cleveland; and (**46a**) upper portion of Knox sandstone in the village of Rhea Springs, Roane County; both in Tennessee.

(**164a**) argillaceo-arenaceous Montevallo shale 2 miles (3.2 km.) north of Montevallo, Shelby County, Alabama.

Fragments of a large *Olenellus* that may belong to this species occur in (**59m**) Weisner quartzite in the Roan Iron Mine, Bartow County, Georgia.

OLENELLUS THOMPSONI CRASSIMARGINATUS, new variety

PLATE 35, FIGS. 8-10

Olenellus thompsoni WALCOTT (in part) [not (Hall)], 1886, Bull. U. S. Geol. Survey, No. 30, pp. 167-168, pl. 17, fig. 1 (not pl. 17, figs. 2, 4, and 9; pl. 22, fig. 1; nor pl. 23, fig. 1 = *Olenellus thompsoni*). (Copies the original description given by Hall [1859, p. 59] and discusses species. Figure 1 is copied in this paper, pl. 35, fig. 8.)

Olenellus thompsoni WALCOTT (in part) [not (HALL)], 1891, Tenth Ann. Rept. U. S. Geol. Survey, pl. 83, fig. 1b (not pl. 82, figs. 1 and 1a; not pl. 83, figs. 1 and 1a = *Olenellus thompsoni*). (No text reference. Figure 1b is copied from Walcott, 1886, pl. 17, fig. 1.)

This variety is founded on a number of specimens of the cephalon with a broad, somewhat flattened marginal rim that in specimens of the same size is proportionally broader than in *Olenellus thompsoni*. The palpebral lobe is also broad.

FORMATION AND LOCALITY.—Lower Cambrian: (**25**) *dark, siliceous shales at Parkers quarry near Georgia, Franklin County, Vermont.*

(**8q**) drab and gray calcareo-argillaceous and arenaceous shales 2 miles (3.2 km.) northwest of the city of York; (**49**) sandstone on Codorus Creek, ⅛ mile (.2 km.) below Meyers Mill, near Emigsville; and (**49a**) sandstone on the Liverpool Road, south of the Schoolhouse 3 miles (4.8 km.) northwest of York; all in York County, Pennsylvania.

OLENELLUS ?? WALCOTTI (Shaler and Foerste)

PLATE 24, FIG. 11

Paradoxides walcotti SHALER and FOERSTE, 1888, Bull. Museum Comp. Zool., Whole Series, Vol. 16, No. 2 (Geol. Series, Vol. 2), pp. 36-37, pl. 2, fig. 12. (Described and discussed. The specimen represented by figure 12 is redrawn in this paper, pl. 24, fig. 11.)

Olenellus walcotti (Shaler and Foerste), WALCOTT, 1891, Tenth Ann. Rept. U. S. Geol. Survey, pp. 636-637, pl. 88, fig. 2. (Reproduces figure and description of Shaler and Foerste [1888, pp. 36-37, pl. 2, fig. 12], and refers species to *Olenellus.*

Olenellus walcotti (Shaler and Foerste), GRABAU, 1900, Occasional Papers, Boston Soc. Nat. Hist., No. 4, Vol. 1, pt. 3, p. 669. (Mentioned.)

Nothing has been added to our knowledge of this species since my paper of 1891. There is not sufficient material to identify it with *Elliptocephala asaphoides* Emmons, nor to positively decide that it is not identical. The cephalon on which the species is founded was found in a stratum of rock carrying six species that are associated with *E. asaphoides* in Rensselaer and Washington counties, New York, namely: *Fordilla troyensis, Stenotheca rugosa, Platyceras primævum, Hyolithes communis emmonsi, H. americanus,* and *Hyolithellus micans.*

FORMATION AND LOCALITY.—Lower Cambrian: (**326d**) reddish-brown arenaceous shale near North Attleboro, Bristol County, Massachusetts.

OLENELLUS ?, sp. undt.

Olenellus sp., MOBERG, 1892, Om Olenellusledet i sydliga Skandinavien, p. 4. (Occurrence mentioned.)

Olenellus ? sp. n., MOBERG, 1899, Geol. Fören. i Stockholm Förhandl., Bd. 21, Häfte 4, pp. 338-339, pl. 15, figs. 18-19. (Preceding reference copied and species discussed.)

Fragments of a species of trilobite that in some respects resembles *Mesonacis torelli* [pl. 26, figs. 5-18] are mentioned by Dr. Moberg

and doubtfully placed under *Olenellus*. His illustrations indicate a large trilobite that, when better specimens are found, may be a species related to, but distinct from, *M. torelli*, or it may be identical with that species.

FORMATION AND LOCALITY.—Phosphatic nodules in green sandstone on the shore, half way between Brantevik and Gislöfshammer, Sweden [Moberg, 1899, p. 338].

OLENELLUS ?, sp. undt.

PLATE 39, FIG. 14

Of this form only one small cephalon, 1.25 mm. in length, has been found in the collections from the *Olenellus lapworthi* zone of northwest Scotland. The elongate slightly tapering glabella and long eye lobes are like those of the young and small cephalons of *Olenellus*, so that for the present the reference is made to that genus. The cephalon is associated with *Olenellus lapworthi, O. reticulatus, O. gigas,* and *Olenelloides armatus.*

FORMATION AND LOCALITY.—Lower Cambrian: argillaceous shale interbedded in "Serpulite grit," a coarse quartzitic sandstone, northern slope of Meal a' Ghubhais, 1,200-1,300 feet (366-396 m.) above Loch Maree, 4 miles (6.4 km.) northwest of Kenlochewe, in the west of Ross-shire, Scotland.

PEACHELLA, new genus[1]

Of this genus only the cephalon of one species is known. This is described under the species *P. iddingsi.*

Genotype.—*Olenellus iddingsi* Walcott [1884, p. 28].

The generic name is given in honor of Dr. B. N. Peach, of the Geological Survey of Scotland.

Stratigraphic range.—In arenaceous shales and thin, interbedded layers of limestone of the Pioche formation, upper part of the Lower Cambrian (Georgian).

Geographic distribution.—Eastern third of Nevada for about 150 miles between the most northern and southern localities.

Observations.—The cephalon of *Peachella* [pl. 40, figs. 17, 18] is distinguished by its blunt, tumid genal spines; elongate, narrow glabella; small eyes and marked convexity. The small eye is not

[1] The type and only species of this genus has been placed under *Olenellus* in the following references: Walcott [1884, p. 28; 1886, p. 170; and 1891, p. 636] and Holm [1887, p. 515].

unlike that of *Olenellus canadensis* [pl. 38, fig. 6], except that it is close to the glabella at its posterior end. The glabella is comparable with that of the very young specimens of *Wanneria gracile* [pl. 38, fig. 22], but in the adult forms of the latter the glabella is broader at the occipital ring. The most nearly related cephalon is that of *O. fremonti,* as expressed in some of its phases of growth [pl. 37, figs. 14-16]. In these specimens the glabella is unusually narrow and the eyes small and near the glabella, and the genal spine is thickened more than usual, but, with the more expanded anterior lobe of the glabella, outward inclination of the eyes, and the impression obtained of the general assemblage of all the characters of the cephalon as seen at one view, there is no danger of confusing the two species. If we consider all the phases of the cephalon of *O. fremonti* as shown on pl. 37 the two forms are at once seen to be widely separated.

We know nothing of the thorax and pygidium, but with such a cephalon it is highly probable that strongly marked characters exist.

PEACHELLA IDDINGSI (Walcott)

PLATE 40, FIGS. 17-19

Olenellus iddingsi WALCOTT, 1884, Monogr. U. S. Geol. Survey, Vol. 8, p. 28, pl. 9, fig. 12. (Described as a new species. The specimen represented by figure 12 is redrawn in this paper, pl. 40, fig. 17, other specimens being used to restore broken portions.)

Olenellus iddingsi WALCOTT, 1886, Bull. U. S. Geol. Survey, No. 30, p. 170, pl. 19, fig. 1. (Reproduces the description and figure given by Walcott in 1884, and adds a paragraph on some specimens from a new locality.)

Olenellus iddingsi Walcott, HOLM, 1887, Geol. Fören. i Stockholm Förhandl., Bd. 9, Häfte 7, p. 515. (Described in Swedish.)

Olenellus iddingsi WALCOTT, 1891, Tenth Ann. Rept. U. S. Geol. Survey, p. 636, pl. 84, fig. 2. (No text reference. Figure 2 is copied from Walcott, 1884, pl. 9, fig. 12.)

Outline of cephalon roughly subtriangular with the length one-half the breadth at the genal angles; strongly convex in front and sloping to the posterior margin, or the outer margin slopes up toward the genal angles; marginal border narrow and wire-like in front and along the antero-lateral curvature of the border; when opposite the eyes the rounded border thickens and broadens so that it passes into the genal spine with a size and convexity that gives it the appearance of a distinctly elongated lobe; the genal spine is short, and in the larger specimens almost blunt in its outline; the posterior border is faintly defined between the glabella and genal

spine as a nearly flat border that in a small cephalon, 3.5 mm. in length, has a short, blunt intergenal spine close to the genal spine, very much as in *Callavia bröggeri* [pl. 27, fig. 1]. Glabella narrow, convex and contracting slightly at the sides from the occipital ring to the anterior lobe which widens and curves abruptly downward nearly to the front marginal rim of the cephalon; it is divided by four nearly transverse furrows into three narrow transverse lobes and a large anterior lobe; the anterior lobe expands in front of the eyes and curves over and down to just within the front marginal border which is broadly and slightly arched upward at its lower margin in front of the glabella: the two posterior transverse lobes of the glabella are longitudinally subequal in width and wider than the second lobe; occipital ring widening from the sides toward the posterior center where a small node occurs. Eyes small, about one-third the length of the cephalon: they rise abruptly from the cheeks and are very prominent when viewed from the side, although not raised above the level of the glabella; palpebral lobe defined from the anterior lobe of the glabella by a shallow furrow; it arches backward close to the glabella to a point opposite the center of the posterior transverse glabellar lobe; the cheeks slope rather abruptly up from the marginal border to the base of the eye; the interior of each cheek is marked by a narrow depressed line or furrow that extends with a gentle sigmoid curvature backward and outward to where it crosses the marginal border a short distance from the genal spine; in one specimen it crosses the border obliquely and disappears at the intergenal spine; this furrow appears to indicate the course of a facial suture back of the eye that is in a state of symphysis. In my original description [Walcott, 1884, p. 28] I called this line the facial suture. No trace of anything indicating a facial suture has been seen in front of the eye.

Surface minutely punctate with faint, irregular, very slightly elevated, narrow ridges that form an irregular network of elongated meshes. The outer surface usually adheres to the matrix to such an extent that only a few fragments show it at all.

Dimensions.—The largest cephalon in the collection has a length of 13 mm., width 26 mm.; convexity at anterior lobe of glabella 4 mm. Width of glabella at occipital ring 5 mm., at widest part of anterior lobe 5.5 mm.; length of eye 3.5 mm.

Thorax and pygidium unknown.

Observations.—This very unusual form is abundantly represented in the Nevada and Utah area of the Cordilleran Cambrian by many

fragments of the cephalon in association with *Olenellus fremonti.* It is readily recognized by the thick, obtuse genal spines of the adult, slender glabella, and small eyes.

The known stratigraphic range of *Peachella iddingsi* is in the arenaceous shales and interbedded siliceous limestone of the Pioche formation near the top of the Lower Cambrian. At the south end of the Timpahute range the following species are associated with it:

Nisusia (*Jamesella*) *erecta* Walcott.
Billingsella highlandensis Walcott.
Callavia nevadensis Walcott.
Olenellus fremonti Walcott.

On Prospect Peak, in the Eureka District, 145 miles north, *Olenellus fremonti* and *Protypus* sp. occur with it, and in the Highland Range 60 miles northeast of the Timpahute Range locality *O. fremonti* and *Callavia nevadensis* are found in the same hand specimens.

Formation and Locality.—Lower Cambrian Pioche formation: (52) *arenaceous shales above the massive-bedded sandstones of the Prospect Mountain formation on the summit of Prospect Mountain, Eureka District, Eureka County;* (30) arenaceous shales on west slope of the Highland Range at the edge of the desert, 8 miles (12.8 km.) north of Bennetts Spring and about 8 miles (12.8 km.) west of Pioche, Lincoln County; (**60h** and **313g**) arenaceous shales and thin, interbedded limestone in the Groom Mining District at the south end of the Timpahute Range, near the line between Nye and Lincoln counties; all in Nevada.

Genus OLENELLOIDES Peach

Olenellus (*Olenelloides*) Peach, 1894, Quart. Journ. Geol. Soc. London, Vol. 50, pp. 668-669, and 671-674. (Described and discussed as a new subgenus.)

Olenelloides (Peach), Beecher, 1897, American Journ. Sci., 4th ser., Vol. 3, p. 191. (Suggests that the genus represents the young of *Olenellus* or a related form.)

Olenelloides (Peach), Moberg, 1899, Geol. Fören. i Stockholm Förhandl., Bd. 21, Häfte 4, p. 320. (Brief description of genus.)

Dorsal shield small, elongate, narrowing from the broad, large cephalon to the small, narrow pygidium.

Cephalon large and provided with strong intergenal, genal, and antero-lateral spines; the intergenal spines appear to represent the postero-lateral termination of the facial sutures, and the antero-

lateral their anterior terminations at the margin, although the sutures are in a condition of symphysis and do not show on the specimens. Glabella subconical and divided by four transverse furrows into a globose anterior lobe and three, narrow, transverse lobes; occipital ring strong and with a minute median node; palpebral lobes small and united to the anterior lobe of the glabella by short ridges. No traces of facial sutures. Interpalpebral ridge crossed by faint furrows indicating the continuation of the glabellar lobes across the dorsal furrow out into the interpalpebral ridge.[1] The third glabellar lobe continues out into the intergenal spine.

Thorax with seven segments. Axial lobe large, convex; pleural lobes narrow and with the third, sixth, and seventh pair extended into long spines; pleural groove strong and obliquely transverse.

Pygidium a small plate with only one transverse furrow as far as known. It is almost enclosed by the spinous extension of the pleuræ of the seventh segment.

Surface marked by a very fine network of slightly raised, very narrow, irregular ridges.

The largest dorsal shield has a length of about 11 mm., the greater number of specimens are smaller.

Genotype.—Olenelloides armatus Peach.

Stratigraphic range.—Upper beds of Lower Cambrian in association with *Olenellus lapworthi.*

Geographic distribution.—Northwest of Scotland, about upper portion of Loch Maree.

Observations.—This is essentially a larval form of *Olenellus.* The large cephalon and narrow thorax indicate this, and there are additional characters to be considered, such as the spinous extensions of the intergenal angles and antero-lateral angles similar to those in the young of *Olenellus gilberti* [pl. 36, figs. 11-14]. The glabella is conical and primitive as in *Nevadia* [pl. 23]. Eyes primitive and with an interpalpebral ridge as in the young of *Olenellus gilberti* [pl. 36, figs. 11, 12], *Elliptocephala* [pl. 25, figs. 9 and 10], and *Pædeumias transitans* [pl. 25, figs. 21 and 22]. The narrow pleural lobes suggest the pleural lobes of the young of *Pædeumias transitans* [pl. 32, figs. 4-6]. The spines of the third and sixth segments indicate a degenerate form.

[1] The interpalpebral ridge is the ridge or elongated tubercle between the glabella and palpebral lobe that is formed by the extension of the three posterior glabellar lobes. These are well shown in the young cephalon of *Elliptocephala asaphoides* [pl. 25, figs. 9 and 10].

I regard *Olenelloides* as representing a degenerate form of the Mesonacidæ that came into existence shortly before the decadence and disappearance of the family.

Mr. B. N. Peach [1894, p. 668] stated when proposing the name *Olenelloides* that the name was "intended to show its strong likeness to some larval stages of other *Olenellids*."

Dr. Charles E. Beecher later [1897, p. 191] suggested that this genus might be the young of *Olenellus* or some related form. I think, now that we have so much additional information about the young stages of the Mesonacidæ, that it may be considered, as just stated, as representing a degenerate genus of the Mesonacidæ.

OLENELLOIDES ARMATUS Peach

PLATE 40, FIGS. 2 AND 3

Olenellus (*Olenelloides*) *armatus* PEACH, 1894, Quart. Journ. Geol. Soc. London, Vol. 50, pp. 669-670, pl. 32, figs. 1-6. (Described. None of the specimens figured are represented in this paper.)

Olenelloides armatus MOBERG, 1899, Geol. Fören. i Stockholm Förhandl., Bd. 21, Häfte 4, pp. 314 and 320, pl. 13, fig. 6. (Mentioned at several places in the text. The figure is copied from Peach, 1894, pl. 32, fig. 3.)

Dr. B. N. Peach has given a very full description of the material illustrating this species that was available when he made his study of it in 1894. Through the courtesy of the Director General of the Geological Survey the specimens studied by Dr. Peach and a number collected since were sent to me by Director Horne of the Scottish Survey. In the material I found one entire dorsal shield and its matrix. The matrix, being the clearer, is illustrated by fig. 3, pl. 40. The following description is drawn from it and the specimen it is the matrix of.

Dorsal shield small, elongate, converging in outline from the broad cephalon to the narrow pygidium; moderately convex.

Cephalon roughly hexagonal with the anterior and posterior sides each equal to the length of two of the shorter right and left sides. The outline is broken by three angles with long spines on each side; the postero-lateral angle corresponds to the intergenal angle of the young cephalon of *Olenellus gilberti* [pl. 36, figs. 11-14]; the median angles and spines correspond to the genal angles of the same, and the antero-lateral angles and spines to similar angles and spines of the young cephalon of *O. gilberti;* the antero-lateral spines are located at the points where the facial suture would apparently terminate on the outer margin. The round marginal rim

merges into the spines at the six angles, and extends inward at the posterior margin to the occipital ring.

Glabella elongate, subcylindrical, and divided by four pairs of transverse furrows into four lobes and an occipital ring; the anterior lobe is nearly circular in outline, globose, and sloping down from the anterior glabellar furrow at an angle of about 45°, to the intermarginal space just within the wire-like marginal rim; the second lobe is broadest at the ends and narrow at the center, owing to the anterior pair of furrows extending obliquely inward and backward while the second pair of furrows are almost at right angles to the sides of the glabella, and united without interruption at the median line so as to form a continuous furrow across the glabella; the third and fourth lobes and occipital ring have approximately the same width; they are separated by the third pair of glabellar furrows which extend inward and a little backward nearly to the median line, where they are united by a more shallow, transverse furrow; on both the third and fourth lobes there is a depressed space on the posterior half of the lobe that extends over about three-fifths of its length; this causes the lobe to have a raised front part connected with ends that appear on the third segment like flattened tubercles, and on the fourth segment, where the depressed space is less extended laterally, as low, elongate tubercles; when the glabella is compressed laterally the ends of the second, third, and fourth lobes have the tubercles or elevated ends of the lobes quite prominent, these resemble the lateral tubercles on the median lobe of the thoracic segments of some forms of *Agnostus* and *Microdiscus*. The ends of the fourth glabellar lobe appear to be united to a low ridge that extends obliquely outward and backward into the intergenal spine on each side; the first lobe is united to the palpebral lobe, while the second and third lobes are connected on each side with the long interpalpebral lobe or tubercle that extends parallel to the glabella from the second lobe to where it merges into the ridge connecting the fourth lobe and the intergenal spine on each side. Occipital ring marked by a shallow, narrow furrow that extends inward from each end at the posterior margin and crosses the ring obliquely nearly to the center just within the anterior margin of the ring. On the broad, transversely subtriangular space thus outlined a sharp, minute node occurs close to the posterior median margin of the ring. The glabella is separated from the other parts of the cephalon by a dorsal furrow that is of varying depth owing to the interruptions caused by the low ridges crossing it from the glabellar lobes; these ridges

are strongest at the first, second, and fourth lobes. Palpebral lobes prominent and extending obliquely outward and backward opposite the posterior half of the first glabellar lobe, and the entire second glabellar lobe; a strong ridge unites the palpebral lobe on each side with the side of the first glabellar lobe; the eye rises abruptly from the surface of the cheek opposite the genal spine and is so curved that the visual surface commands all parts of the dorsal shield except directly back of the glabella. I have not been able to find any trace of a furrow connecting the posterior end of the eye with the intergenal spine; if such existed it would extend along the outside of the longitudinal ridge next to the glabella. The inner slope from the palpebral lobe to the dorsal furrow beside the glabella is quite steep and gives great prominence to the eye. The elongate ridge on each side that rises between the eye and the glabella extends back to where it passes out into the intergenal spine; this interpalpebral ridge appears to be formed of the extensions of the glabellar lobes in the same manner as a somewhat similar ridge on the cephalon of the young of *Elliptocephala asaphoides* [pl. 25, figs. 9, 10]. In one specimen traces of segmentation are preserved on the ridges, and a connecting ridge crosses the dorsal furrow uniting the second and fourth glabellar lobes with the longitudinal ridge. The spaces between the front of the glabella, the eyes, and the longitudinal ridge back of the eyes and the marginal rim are very small and of little importance.

The thorax is largely formed of the axial lobe and spinose extensions of the seven thoracic segments (Dr. Peach mentions eight segments, but I can not make out more than seven). Axial lobe convex and separated from the pleural lobes by a clearly defined dorsal furrow; a minute median tubercle or spine occurs near the posterior margin of the segment and there are slight traces of furrows that begin near the anterior center of the segment and extend obliquely outward and backward to the postero-lateral edge, thus repeating the surface structure of the occipital ring. The first three segments are about as wide as the occipital ring, the others gradually narrow toward the pygidium; pleural lobes narrow; those of the first segment are shorter than their width, or longitudinally quadrilateral in outline; those of the second segment are a little longer than those of the first and those of the fourth and fifth are longer than wide; the pleuræ of the third segment are broader than those of the first and second, and are prolonged into a long spine that extends obliquely outward and backward at about the same angle as the inter-

genal spines of the cephalon; the pleuræ of the sixth segment are also extended in spines similar to those of the third segment, but the spines of the pleuræ of the seventh segment are bent abruptly backward so far that they converge slightly toward the median line; a small, short spine occurs at the postero-lateral angle of each of the pleuræ of the first, second, fourth, and fifth segments; the broad pleural furrow crosses the pleuræ obliquely from the antero-interior side to the postero-lateral side, and occupies the greater part of the surface of the pleuræ, except on the third and sixth segments, where the furrow extends out on the base of the large spinose extension of the pleura.

The pygidium is not shown on the specimens studied by Dr. Peach, but on two specimens collected since 1894 the outlines of a small pygidium can be seen between the incurved spines of the seventh segment; it is without spines or angles; about as long as wide at its point of junction with the seventh segment; roughly rounded, subtriangular in outline and marked by a transverse furrow about midway of its length. The pygidium resembles that of the young of *Pædeumias transitans,* as shown by fig. 4, pl. 32, of this paper.

Surface marked by a very minute network of very fine, irregular elevated lines or ridges.

Dimensions.—The largest specimen of the dorsal shield I have seen has a length of 9 mm., exclusive of the pygidium and spines (Dr. Peach mentions one 11 mm. in length). In an entire dorsal shield 4.5 mm. in length [pl. 40, fig. 3] the cephalon is one-half (2.25 mm.) of the total length; width at the intergenal spines 2.1 mm. The proportions of the various parts of the cephalon are fairly well shown by fig. 2, except that the specimen is a little shortened by distortion.

Observations.—The specimens illustrating this species are fairly well preserved in a very fine, hard argillaceous shale, but most of them have been more or less distorted by compression. A number of specimens of the cephalon have been found, but entire specimens are very rare. The relation of this species to the young of other species of the Mesonacidæ are discussed under remarks on the genus *Olenelloides.*

Formation and Locality.—Lower Cambrian: argillaceous shale interbedded in "Serpulite grit," a coarse quartzitic sandstone, northern slope of Meal a' Ghubhais, 1,200-1,300 feet (366-396 m.) above Loch Maree, 4 miles (6.4 km.) northwest of Kenlochewe in the west of Ross-shire, Scotland.

LIST (ARRANGED BY GENERA, SUBGENERA, AND SPECIES) OF THE FORMS NOW PLACED IN THE MESONACIDÆ, AS THEY OCCUR IN THE LITERATURE, WITH THE PRESENT REFERENCE OF EACH

argentus [Olenellus] Walcott (new)	= Olenellus argentus
armatus [Olenelloides] Moberg [1899, pp. 314 and 320, pl. 13, fig. 6]	= Olenelloides armatus
armatus [Olenellus (Olenelloides)] Peach [1894, pp. 669-670, pl. 32, figs. 1-6]	= Olenelloides armatus
asaphoides [Ebenezeria] Marcou [1888b, p. 123]	= Elliptocephala asaphoides
asaphoides [Eliptocephalus] Emmons [1849, p. 18]	= Elliptocephala asaphoides
asaphoides [Eliptocephalus] Emmons [1855, p. 114, figs. 1-3, pl. 1, fig. 18]	= Elliptocephala asaphoides
asaphoides [Eliptocephalus (Paradoxides)] Emmons [1860, p. 280]	= Olenellus thompsoni
asaphoides [Elliptocephala] Cole [1892, pp. 340-341]	= Elliptocephala asaphoides
asaphoides [Elliptocephala] Emmons [1844, p. 21, figs. 1-3]	= Elliptocephala asaphoides
asaphoides [Elliptocephala] Emmons [1846, p. 65, figs. 1-3]	= Elliptocephala asaphoides
asaphoides [Elliptocephalus] Marcou [1888a, p. 12]	= Elliptocephala asaphoides
asaphoides [Georgiellus] Moberg [1899, p. 316, pl. 13, figs. 1a-b]	= Elliptocephala asaphoides
asaphoides [Mesonacis (Olenellus)] Peach [1894, p. 671; text fig. C, p. 673; and pl. 32, fig. 11]	= Elliptocephala asaphoides
asaphoides [Olenellus] Bernard [1894, pp. 415-416 and 423-424; fig. 3, p. 415; figs. 4a-c and 5, p. 416; and fig. 9, p. 423]	= Elliptocephala asaphoides
asaphoides [Olenellus] Ford [1878, pp. 129-130]	= Elliptocephala asaphoides
asaphoides [Olenellus] Ford [1881, pp. 250-259, figs. 1-3, p. 251]	= Elliptocephala asaphoides
asaphoides [Olenellus] Holm [1887, p. 515]	= Elliptocephala asaphoides
asaphoides [Olenellus] Lesley [1889, p. 489, 10 text figs.]	= Elliptocephala asaphoides
asaphoides [Olenellus] Lindström [1901, pp. 12-18, text figs. 1-10, p. 13]	= Elliptocephala asaphoides
asaphoides [Olenellus] Matthew [1891, p. 289 and footnote]	= Elliptocephala asaphoides
asaphoides [Olenellus] Walcott [1884, pp. 36-37, pl. 21, figs. 10-12]	= Elliptocephala asaphoides
asaphoides [Olenellus] Walcott [1886, pp. 168-170, pl. 17, figs. 3-8 and 10; pl. 20, figs. 3, 3a-b; and pl. 25, fig. 8]	= Elliptocephala asaphoides
asaphoides [Olenellus (Elliptocephalus)] Ford [1877, pp. 265-272, pl. 4, figs. 1-10]	= Elliptocephala asaphoides
asaphoides [Olenellus (Georgiellus)] Pompeckj [1901, p. 16]	= Elliptocephala asaphoides
asaphoides [Olenellus (Mesonacis)] Beecher [1895, p. 176, figs. 6-8, p. 175]	= Elliptocephala asaphoides

LIST (ARRANGED BY GENERA, SUBGENERA, AND SPECIES) OF THE FORMS NOW PLACED IN THE MESONACIDÆ, AS THEY OCCUR IN THE LITERATURE, WITH THE PRESENT REFERENCE OF EACH—Cont'd

asaphoides [Olenellus (Mesonacis)] Burr [1900, p. 45]	= Callavia crosbyi
asaphoides [Olenellus (Mesonacis)] Clarke and Ruedemann [1903, pp. 730-732]	= Elliptocephala asaphoides
asaphoides ? [Olenellus (Mesonacis)] Grabau [1900, pp. 667-669, pl. 34, figs. 2a-b]	= Callavia crosbyi
asaphoides [Olenellus (Mesonacis)] Walcott [1890, p. 41]	= Elliptocephala asaphoides
asaphoides [Olenellus (Mesonacis)] Walcott [1891, pp. 637-638, pl. 86, figs. 3, 3a-b; pl. 88, figs. 1, 1a-g; pl. 89, figs. 1 and 1a; and pl. 90, figs. 1 and 1a]	= Elliptocephala asaphoides
asaphoides [Olenellus (Olenus)] Ford [1871a, p. 33]	= Elliptocephala asaphoides
asaphoides [Olenellus (Olenus)] Ford [1871b, p. 210]	= Elliptocephala asaphoides
asaphoides [Olenus] Fitch [1849, p. 865]	= Elliptocephala asaphoides
asaphoides [Olenus] Hall [1847, pp. 256-257, pl. 67, figs. 2a-c]	= Elliptocephala asaphoides
asaphoides [Paradoxides] Barrande [1861, pp. 273-276, pl. 5, figs. 4-5]	= Elliptocephala asaphoides
asaphoides [Paradoxides] Emmons [1860, p. 87, legend of fig. 70]	= Olenellus thompsoni
Barrandia Hall [1860, p. 115]	= Mesonacis (in part) and Olenellus (in part)
Barrandia Hall [1861, p. 369]	= Mesonacis (in part) and Olenellus (in part)
Barrandia McCoy ... does not	= Olenellus
Barrandia thompsoni Hall [1860, pp. 115-116, fig., p. 116]	= Olenellus thompsoni
Barrandia thompsoni Hall [1861, pp. 369-370]	= Olenellus thompsoni
Barrandia thompsoni Hall [1862a, pl. 13, fig. 1]	= Olenellus thompsoni
Barrandia vermontana Hall [1860, p. 117, text fig.]	= Mesonacis vermontana
Barrandia vermontana Hall [1861, p. 370]	= Mesonacis vermontana (in part) and Pædeumias transitans (in part)
Barrandia vermontana Hall [1862a, pl. 13, fig. 2]	= Mesonacis vermontana
Barrandia vermontana Hall [1862a, pl. 13, figs. 4 and 5]	= Pædeumias transitans
bicensis [Callavia] Walcott (new)	= Callavia bicensis

brachycephalus [Paradoxides] Emmons [1860, first edition, p. 87]	= Olenellus thompsoni
bröggeri [Callavia] Matthew [1897, p. 397, footnote]	= Callavia bröggeri
bröggeri [Cephalacanthus] Lapworth [1891a, p. 641]	= Callavia bröggeri
brœggeri [Holmia ?] Marcou [1890, pp. 370-371]	= Callavia bröggeri
bröggeri [Holmia] Peach [1894, pp. 672 and 673]	= Callavia bröggeri
bröggeri [Olenellus] Bernard [1894, p. 423]	= Callavia bröggeri
bröggeri [Olenellus] Walcott [1888, p. 551]	= Callavia bröggeri
bröggeri [Olenellus (Holmia)] Burr [1900, pp. 43-44]	= Callavia crosbyi
bröggeri [Olenellus (Holmia)] Grabau [1900, pp. 662-664, pl. 33, figs. 1a-j]	= Callavia crosbyi
brœggeri [Olenellus (Holmia)] Pompeckj [1901, pl. 1, fig. 10]	= Callavia bröggeri
bröggeri [Olenellus (Holmia)] Walcott [1891a, pp. 638-640, pl. 91, fig. 1; pl. 92, figs. 1, 1a-h]	= Callavia bröggeri
bröggeri [Olenellus (Mesonacis)] Walcott [1889, pp. 378-380]	= Callavia bröggeri
bröggeri [Olenellus (Mesonacis)] Walcott [1890, p. 41]	= Callavia bröggeri
burri [Callavia] Walcott (new)	= Callavia burri
calevi [Olenellus (Holmia)] Walcott [1891a, p. 635]	= Callavia callavei
callavei [Cephalacanthus] Lapworth [1891a, pp. 640-641]	= Callavia callavei
callavei [Olenellus] Lapworth [1888a, p. 485]	= Callavia callavei
callavei [Olenellus] Lapworth [1888b, p. 212]	= Callavia callavei
callavei [Olenellus (Holmia)] Cole [1892, pp. 344 and 345]	= Callavia callavei
callavei [Olenellus (Holmia)] Lapworth [1891b, pp. 530-536, pl. 14, figs. 1-25, and pl. 15]	= Callavia callavei
Callavia Matthew [1897, p. 397, footnote]	= Callavia
Callavia bicensis Walcott (new)	= Callavia bicensis
Callavia bröggeri Matthew [1897, p. 397, footnote]	= Callavia bröggeri
Callavia burri Walcott (new)	= Callavia burri
Callavia callavii Matthew [1897, p. 397, footnote]	= Callavia callavei
Callavia crosbyi Walcott (new)	= Callavia crosbyi
Callavia ? nevadensis Walcott (new)	= Callavia ? nevadensis
callavii [Callavia] Matthew [1897, p. 397, footnote]	= Callavia callavei
canadensis [Olenellus] Walcott [1908b, p. 242]	= Olenellus canadensis (in part) and Olenellus gilberti (in part)

LIST (ARRANGED BY GENERA, SUBGENERA, AND SPECIES) OF THE FORMS NOW PLACED IN THE MESONACIDÆ, AS THEY OCCUR IN THE LITERATURE, WITH THE PRESENT REFERENCE OF EACH—Cont'd

canadensis [Olenellus] Walcott [1908c, p. 215]	= Olenellus canadensis (in part) and Olenellus gilberti (in part)
cartlandi [Olenellus (Holmia ?)] Raw [1909, MS.]	= Callavia cartlandi
Cephalacanthus Lacépède [1802, p. 323]	= Fish
Cephalacanthus Lapworth [1891a, p. 641]	= Callavia (in part) and Holmia (in part)
Cephalacanthus Lapworth [1891b, p. 531]	= Callavia (in part) and Holmia (in part)
Cephalacanthus bröggeri Lapworth [1891a, p. 641]	= Callavia bröggeri
Cephalacanthus callavei Lapworth [1891a, pp. 640-641]	= Callavia callavei
Cephalacanthus kjerulfi Lapworth [1891a, pp. 640-641]	= Holmia kjerulfi
claytoni [Olenellus] Walcott [1908c, p. 189, 6 of section]	= Olenellus gilberti (in part) and Olenellus claytoni (in part)
crassimarginatus [Olenellus thompsoni] Walcott (new)	= Olenellus thompsoni crassimarginatus
crosbyi [Callavia] Walcott (new)	= Callavia crosbyi
Ebenezeria Marcou [1888, p. 123]	= Elliptocephala
Ebenezeria asaphoides Marcou [1888b, p. 123]	= Elliptocephala asaphoides
Eliptocephalus Emmons [1849, p. 18]	= Elliptocephala
Eliptocephalus Emmons [1855, pp. 114-115]	= Elliptocephala
Eliptocephalus Marcou [1860, p. 371]	= Elliptocephala
Eliptocephalus asaphoides Emmons [1849, p. 18]	= Elliptocephala asaphoides
Eliptocephalus asaphoides Emmons [1855, p. 114, figs. 1-3, pl. 1, fig. 18]	= Elliptocephala asaphoides
Eliptocephalus (Paradoxides) asaphoides Emmons [1860, p. 280]	= Olenellus thompsoni
Elliptocephala Beecher [1897, pp. 191 and 192]	= Elliptocephala
Elliptocephala Cole [1892, p. 340]	= Elliptocephala
Elliptocephala Emmons [1844, p. 21]	= Elliptocephala

Elliptocephala Emmons [1846, p. 65]	= Elliptocephala
Elliptocephala Matthew [1899, p. 59]	= Elliptocephala
Elliptocephala asaphoides Cole [1892, pp. 340-341]	= Elliptocephala asaphoides
Elliptocephala asaphoides Emmons [1844, p. 21, figs. 1-3]	= Elliptocephala asaphoides
Elliptocephala asaphoides Emmons [1846, p. 65, figs. 1-3]	= Elliptocephala asaphoides
Elliptocephala thompsoni Miller [1889, p. 546, fig. 1003]	= Olenellus thompsoni
Elliptocephala (Mesonacis) Beecher [1897, p. 192]	= Mesonacis
Elliptocephalus Marcou [1890, p. 362]	= Elliptocephala
(Elliptocephalus) [Olenellus] Ford [1877, pp. 265-272]	= Elliptocephala
Elliptocephalus asaphoides Marcou [1888a, p. 12]	= Elliptocephala asaphoides
(Elliptocephalus) asaphoides [Olenellus] Ford [1877, pp. 265-272, pl. 4, figs. 1-10]	= Elliptocephala asaphoides
Elliptocephalus (Schmidtia) Marcou [1890, p. 363]	= Mesonacis (in part) and Zacanthoides (in part)
Elliptocephalus (Schmidtia) mickwitzi Marcou [1890, p. 363]	= Mesonacis mickwitzi
Elliptocephalus (Schmidtia) vermontana Marcou [1890, p. 363]	= Mesonacis vermontana
elongatus [Olenellus lapworthi] Peach [1894, p. 664, pl. 29, figs. 3-6]	= Olenellus lapworthi
fremonti [Olenellus] Walcott [1908c, p. 187]	= Olenellus fremonti
Gen. ? Matthew [1888, pp. 75-76]	= Holmia
(Gen. ?) kjerulfi [Paradoxides] Matthew [1888, pp. 75-76]	= Holmia kjerulfi
Georgiellus Moberg [1899, p. 317]	= Elliptocephala
(Georgiellus [Olenellus] Pompeckj [1901, p. 16]	= Elliptocephala
Georgiellus asaphoides Moberg [1899, p. 316, pl. 13, figs. 1a-b]	= Elliptocephala asaphoides
(Georgiellus) asaphoides [Olenellus] Pompeckj [1901, p. 16]	= Elliptocephala asaphoides
gigas [Olenellus] Peach [1894, p. 666, fig. 1, p. 667]	= Olenellus gigas
gilberti [Olenellus] Holm [1887, pp. 514-515]	= Olenellus gilberti
gilberti [Olenellus] Lesley [1889, p. 490, whole specimens represented by figs. 1 and 1a]	= Olenellus gilberti
gilberti [Olenellus] Lesley [1889, p. 490, fig 2a and cephalons represented by figs. 1, 1a, 1b, and 1f]	= Olenellus fremonti
gilberti [Olenellus] McConnell [1887, p. 30D]	= Wanneria gracile

LIST (ARRANGED BY GENERA, SUBGENERA, AND SPECIES) OF THE FORMS NOW PLACED IN THE MESONACIDÆ, AS THEY OCCUR IN THE LITERATURE, WITH THE PRESENT REFERENCE OF EACH—Cont'd

gilberti [Olenellus] Meek [1874, MS.]	= Olenellus gilberti
gilberti [Olenellus] Peach [1894, p. 671, pl. 32, figs. 9 and 10]	= Olenellus fremonti
gilberti [Olenellus] Walcott [1884, p. 29, pl. 9, fig. 16, and pl. 21, fig. 13]	= Callavia ? nevadensis
gilberti [Olenellus] Walcott [1884, p. 29, pl. 9, fig. 16a]	= Olenellus fremonti
gilberti [Olenellus] Walcott [1884, p. 29, pl. 21, fig. 14]	= Olenellus gilberti
gilberti [Olenellus] Walcott [1886, pp. 170-180, pl. 18, figs. 1, 1a-b; pl. 19, figs. 2, 2a, 2b, 2k; pl. 20, fig. 4; and pl. 21, figs. 1 and 1a]	= Olenellus gilberti
gilberti [Olenellus] Walcott [1886, pp. 170-180, pl. 18, fig. 1c; pl. 19, figs. 2e, 2h, 2i; pl. 20, figs. 1, 1a-i, 1k-m; and pl. 21, figs. 2 and 2a]	= Olenellus fremonti
gilberti [Olenellus] Walcott [1886, pp. 170-180, pl. 19, figs. 2c, 2d, 2f, and 2g]	= Callavia ? nevadensis
gilberti [Olenellus] Walcott [1891a, pl. 84, figs. 1, 1a-c; pl. 85, figs. 1b-d; and pl. 86, fig. 4]	= Olenellus gilberti
gilberti [Olenellus] Walcott [1891a, pl. 84, figs. 1d and 1f; pl. 85, figs. 1, 1a, and 1f; and pl. 86, figs. 1, 1a-i, 1k-m]	= Olenellus fremonti
gilberti [Olenellus] Walcott [1891a, pl. 84, figs. 1e and 1g; and pl. 85, figs. 1e and 1g]	= Callavia ? nevadensis
gilberti [Olenellus] Walcott [1908c, p. 189, 2 of section]	= Olenellus gilberti
gilberti [Olenellus] White [1874, p. 7]	= Olenellus gilberti
gilberti [Olenellus] White [1877, pp. 44-46, pl. 2, figs. 3a-e]	= Olenellus gilberti
gilberti [Olenus (Olenellus)] Gilbert [1875, pp. 182-183]	= Olenellus gilberti
gilberti var. [Olenellus] Walcott (new)	= Olenellus gilberti var.
gracile [Wanneria ?] Walcott (new)	= Wanneria ? gracile
halli [Wanneria] Walcott (new)	= Wanneria halli
Holmia Beecher [1897, p. 191]	= Holmia
Holmia Cole [1892, p. 344]	= Holmia
Holmia Frech [1897, p. 41]	= Holmia
Holmia Lindström [1901, p. 24]	= Holmia
Holmia Marcou [1890, pp. 365-366]	= Holmia
Holmia Matthew [1890, p. 160, footnote]	= Holmia

Holmia Matthew [1899, p. 59]	= Holmia
Holmia Moberg [1899, pp. 314 and 318]	= Holmia (in part) and Callavia (in part)
Holmia Peach and Horne [1892, p. 236]	= Holmia (in part) and Callavia (in part)
Holmia Pompeckj [1901, pp. 14-17]	= Holmia
Holmia Weller [1900, pp. 50-51]	= Holmia
(Holmia) [Olenellus] Cole [1892, fig. 3, p. 343]	= Holmia
Holmia ? brœggeri Marcou [1890, pp. 370-371]	= Callavia bröggeri
Holmia bröggeri Peach [1894, pp. 672 and 673]	= Callavia bröggeri
(Holmia) bröggeri [Olenellus] Burr [1900, pp. 43-44]	= Callavia crosbyi
(Holmia) bröggeri [Olenellus] Grabau [1900, pp. 662-664, pl. 33, figs. 1a-j]	= Callavia crosbyi
(Holmia) brœggeri [Olenellus] Pompeckj [1901, pl. 1, fig. 10]	= Callavia bröggeri
(Holmia) bröggeri [Olenellus] Walcott [1891a, pp. 638-640, pl. 91, fig. 1; pl. 92, figs. 1, 1a-h]	= Callavia bröggeri
(Holmia) calevi [Olenellus] Walcott [1891a, p. 635]	= Callavia callavei
(Holmia) callavei [Olenellus] Cole [1892, pp. 344 and 345]	= Callavia callavei
(Holmia) callavei [Olenellus] Lapworth [1891b, pp. 530-536, pl. 14, figs. 1-25, and pl. 15]	= Callavia callavei
(Holmia ?) cartlandi [Olenellus] Raw [1909, MS.]	= Callavia cartlandi
Holmia kjerulfi Lindström [1901, p. 57]	= Holmia kjerulfi
Holmia kjerulfi Marcou [1890, pp. 365-366]	= Holmia kjerulfi
Holmia kjerulfi Moberg [1899, p. 318, pl. 13, fig. 3]	= Holmia kjerulfi
(Holmia) kjerulfi [Olenellus] Cole [1892, p. 343, fig. 3]	= Holmia kjerulfi
(Holmia) kjerulfi [Olenellus] Frech [1897, pl. 1a, fig. 13]	= Holmia kjerulfi
(Holmia) kjerulfi [Olenellus] Walcott [1891a, p. 635, pl. 86, fig. 2, and pl. 93, fig. 2]	= Holmia kjerulfi
Holmia lundgreni Lindström [1901, p. 57]	= Holmia lundgreni
Holmia lundgreni Moberg [1899, pp. 321-329, pl. 14, figs. 1-14]	= Holmia lundgreni
Holmia rowei Walcott [1908c, p. 186, 1d and 2j of section]	= not specifically identified
Holmia rowei Walcott [1908c, pp. 187 and 188, 3 of section]	= Wanneria ? gracile
Holmia rowei Walcott [1908c, p. 189, 3 of section]	= Olenellus argentus (in part) and Olenellus gilberti (in part)

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LIST (ARRANGED BY GENERA, SUBGENERA, AND SPECIES) OF THE FORMS NOW PLACED IN THE MESONACIDÆ, AS THEY OCCUR IN THE LITERATURE, WITH THE PRESENT REFERENCE OF EACH—Cont'd

Holmia rowei Walcott [1908c, p. 189, 12 of section]	= Holmia rowei
(Holmia) walcottanus [Olenellus] Wanner [1901, pp. 267-269, pl. 31, figs. 1 and 2; pl. 32, figs. 1-4]	= Wanneria walcottanus
Holmia weeksi Walcott [1908c, p. 187, 2j of section]	= Olenellus fremonti
Holmia weeksi Walcott [1908c, p. 189, 3 of section]	= Wanneria ? gracile
Holmia weeksi Walcott [1908c, p. 189, 6 of section]	= Olenellus fremonti
Holmia weeksi Walcott [1908c, p. 189, 11 of section]	= not specifically identified
Holmia weeksi Walcott [1908c, p. 189, 12 of section]	= Nevadia weeksi
Holmia (Olenellus) Peach [1894, pp. 671-674]	= Holmia (in part) and Callavia (in part)
Holmia (Olenellus) kjerulfi Peach [1894, p. 671, pl. 32, fig. 12]	= Holmia kjerulfi
howelli [Olenellus] Meek [1874, MS.]	= Olenellus gilberti
howelli [Olenellus] Walcott [1884, pp. 30-31, pl. 9, figs. 15, 15a-c; and pl. 21, figs. 1-9, 16-17]	= Olenellus fremonti
howelli [Olenellus] White [1874, p. 8]	= Olenellus gilberti
howelli [Olenellus] White [1877, pp. 47-48, pl. 2, figs. 4a-b]	= Olenellus gilberti
howelli [Olenus (Olenellus)] Gilbert [1875, p. 183]	= Olenellus gilberti
iddingsi [Olenellus] Holm [1887, p. 515]	= Peachella iddingsi
iddingsi [Olenellus] Walcott [1884, p. 28, pl. 9, fig. 12]	= Peachella iddingsi
iddingsi [Olenellus] Walcott [1886, p. 170, pl. 19, fig. 1]	= Peachella iddingsi
iddingsi [Olenellus] Walcott [1891a, p. 636, pl. 84, fig. 2]	= Peachella iddingsi
intermedius [Olenellus] Peach [1894, pp. 666-668, pl. 32, fig. 7]	= Olenellus lapworthi
kjerulfi [Cephalacanthus] Lapworth [1891a, pp. 640-641]	= Holmia kjerulfi
kjerulfi [Holmia] Lindström [1901, p. 57]	= Holmia kjerulfi
kjerulfi [Holmia] Marcou [1890, pp. 365-366]	= Holmia kjerulfi
kjerulfi [Holmia] Moberg [1899, p. 318, pl. 13, fig. 3]	= Holmia kjerulfi
kjerulfi [Holmia (Olenellus)] Peach [1894, p. 671, pl. 32, fig. 12]	= Holmia kjerulfi
kjerulfi [Paradoxides] Ford [1878, p. 130, footnote]	= Holmia kjerulfi

kjerulfi [Olenellus] Brögger [1878, p. 44] .... = Holmia kjerulfi
kjerulfi [Olenellus] Holm [1887, pp. 499-512] .... = Holmia kjerulfi
kjerulfi [Olenellus] Koken [1896, p. 7, fig. 2] .... = Holmia kjerulfi
kjerulfi [Olenellus] Linnarsson [1883, pp. 18-20, pl. 3, figs. 12-17] .... = Holmia kjerulfi
kjerulfi [Olenellus (Holmia)] Cole [1892, p. 343, fig. 3] .... = Holmia kjerulfi
kjerulfi [Olenellus (Holmia)] Frech [1897, pl. 1a, fig. 13] .... = Holmia kjerulfi
kjerulfi [Olenellus (Holmia)] Walcott [1891a, p. 635, pl. 86, fig. 2, and pl. 93, fig. 2] .... = Holmia kjerulfi
kjerulfi [Olenellus (?)] Matthew [1886, pp. 472-473] .... = Holmia kjerulfi
kjerulfi [Paradoxides ?] Ford [1881, pp. 255-258, fig. 10, p. 256] .... = Holmia kjerulfi
kjerulfi [Paradoxides] Kjerulf [1873, p. 83, figs. 1-5] .... = Holmia kjerulfi
kjerulfi [Paradoxides] Linnarsson [1871, pp. 790-792, pl. 16, figs. 1-3] .... = Holmia kjerulfi
kjerulfi [Paradoxides] Walcott [1886, p. 178, pl. 20, fig. 2] .... = Holmia kjerulfi
kjerulfi [Paradoxides (Gen. ?)] Matthew [1888, pp. 75-76] .... = Holmia kjerulfi
lapworthi [Olenellus] Peach [1894, pp. 662-664, pl. 29, figs. 1, 2, and 2a; pl. 30, fig. 7; and pl. 32, fig. 8] .... = Olenellus lapworthi
lapworthi [Olenellus] Peach and Horne [1892, pp. 236-241, pl. 5, figs. 1-11] .... = Olenellus lapworthi
lapworthi elongatus [Olenellus] Peach [1894, p. 664, pl. 29, figs. 3-6] .... = Olenellus lapworthi
logani [Olenellus] Walcott (new) .... = Olenellus logani
lundgreni [Holmia] Lindström [1901, p. 57] .... = Holmia lundgreni
lundgreni [Holmia] Moberg [1899, pp. 321-329, pl. 14, figs. 1-14] .... = Holmia lundgreni
lundgreni [Olenellus] Moberg [1892, p. 3] .... = Holmia lundgreni
macrocephalus [Paradoxides] Barrande [1861, pp. 276-277, pl. 5, fig. 7] .... = Olenellus thompsoni
macrocephalus [Paradoxides] Emmons [1860, p. 87 and p. 280] .... = Olenellus thompsoni
magnificus ? [Metadoxides] Grabau [1900, p. 670, pl. 34, figs. 4-6] .... = Callavia crosbyi
Mesonacis Cole [1892, pp. 342-344] .... = Mesonacis
Mesonacis Moberg [1899, p. 318] .... = Mesonacis
Mesonacis Peach and Horne [1892, p. 236] .... = Elliptocephala (in part) and Mesonacis (in part)
Mesonacis Walcott [1886, p. 158] .... = Mesonacis

LIST (ARRANGED BY GENERA, SUBGENERA, AND SPECIES) OF THE FORMS NOW PLACED IN THE MESONACIDÆ, AS THEY OCCUR IN THE LITERATURE, WITH THE PRESENT REFERENCE OF EACH—Cont'd

Mesonacis Walcott [1885, pp. 328-330]	= Mesonacis
Mesonacis Weller [1900, pp. 50-51]	= Mesonacis
(Mesonacis) [Elliptocephala] Beecher [1897, p. 192]	= Mesonacis
(Mesonacis) [Olenellus] Cole [1892, fig. 2, p. 343]	= Mesonacis
(Mesonacis) [Olenellus] Walcott [1891a, p. 637]	= Elliptocephala (in part) and Mesonacis (in part)
Mesonacis mickwitziae Peach [1894, p. 672, text fig. B, p. 673]	= Mesonacis mickwitzi
Mesonacis vermontana Moberg [1899, p. 318, pl. 13, fig. 4]	= Mesonacis vermontana
Mesonacis vermontanus Walcott [1885, pp. 328-330, figs. 1 and 2, p. 329]	= Mesonacis vermontana
Mesonacis vermontanus Walcott [1886, pp. 158-162, pl. 24, figs. 1, 1a-b]	= Mesonacis vermontana
(Mesonacis) asaphoides [Olenellus] Beecher [1895, p. 176, figs. 6-8, p. 175]	= Elliptocephala asaphoides
(Mesonacis) asaphoides [Olenellus] Burr [1900, p. 45]	= Callavia crosbyi
(Mesonacis) asaphoides [Olenellus] Clarke and Ruedemann [1903, pp. 730-732]	= Elliptocephala asaphoides
(Mesonacis) asaphoides ? [Olenellus] Grabau [1900, pp. 667-669, pl. 34, figs. 2a-b]	= Callavia crosbyi
(Mesonacis) asaphoides [Olenellus] Walcott [1890, p. 41]	= Elliptocephala asaphoides
(Mesonacis) asaphoides [Olenellus] Walcott [1891, pp. 637-638, pl. 86, figs. 3, 3a-b; pl. 88, figs. 1, 1a-g; pl. 89, figs. 1 and 1a; and pl. 90, figs. 1 and 1a]	= Elliptocephala asaphoides
(Mesonacis) bröggeri [Olenellus] Walcott [1889, pp. 378-380]	= Callavia bröggeri
(Mesonacis) bröggeri [Olenellus] Walcott [1890, p. 41]	= Callavia bröggeri
(Mesonacis) mickwitzi [Olenellus] Frech [1897, pl. 1a, fig. 8]	= Mesonacis mickwitzi
(Mesonacis) mickwitzi [Olenellus] Walcott [1891, p. 634, pl. 93, fig. 1]	= Mesonacis mickwitzi
(Mesonacis) vermontana [Olenellus] Cole [1892, pp. 340 and 341, fig. 2, p. 343]	= Mesonacis vermontana
(Mesonacis) vermontana [Olenellus] Walcott [1891a, p. 637, pl. 87, figs. 1, 1a-b]	= Mesonacis vermontana
Mesonacis (Olenellus) Peach [1894, pp. 671-674]	= Elliptocephala (in part) and Mesonacis (in part)
Mesonacis (Olenellus) asaphoides Peach [1894, p. 671; text fig. C, p. 673; and pl. 32, fig. 11]	= Elliptocephala asaphoides
Metadoxides magnificus ? Grabau [1900, p. 670, pl. 34, figs. 4-6]	= Callavia crosbyi

mickwitzi [Elliptocephalus (Schmidtia)] Marcou [1890, p. 363]	= Mesonacis mickwitzi
mickwitzi [Olenellus] Schmidt [1888, pp. 13-19, pl. 1, figs. 1-25]	= Mesonacis mickwitzi
mickwitzi [Olenellus] Schmidt [1889, pp. 191-195, 10 text figs., p. 193]	= Mesonacis mickwitzi
mickwitzi [Olenellus (Mesonacis)] Frech [1897, pl. 1a, fig. 8]	= Mesonacis mickwitzi
mickwitzi [Olenellus (Mesonacis)] Walcott [1891a, p. 634, pl. 93, fig. 1]	= Mesonacis mickwitzi
mickwitzi [Schmidtia] Moberg [1899, pp. 319-320, pl. 13, figs. 5a-c]	= Mesonacis mickwitzi
mickwitzi [Schmidtiellus] Moberg, Moberg and Segerberg [1906, p. 35, footnote]	= Mesonacis mickwitzi
mickwitziae [Mesonacis] Peach [1894, p. 672, text fig. B, p. 673]	= Mesonacis mickwitzi
nevadensis [Callavia?] Walcott (new)	= Callavia ? nevadensis
Nevadia Walcott (new)	= Nevadia
Nevadia weeksi Walcott (new)	= Nevadia weeksi
Olenelloides Beecher [1897, p. 191]	= Olenelloides
Olenelloides Moberg [1899, p. 320]	= Olenelloides
(Olenelloides) [Olenellus] Peach [1894, pp. 668-669, and 671-674]	= Olenelloides
Olenelloides armatus Moberg [1899, pp. 314 and 320, pl. 13, fig. 6]	= Olenelloides armatus
(Olenelloides) armatus [Olenellus] Peach [1894, pp. 669-670, pl. 32, figs. 1-6]	= Olenelloides armatus
Olenellus Beecher [1897, p. 191]	= Olenellus
Olenellus Bernard [1894, pp. 415-416]	= Elliptocephala
Olenellus Cole [1892, pp. 340-346]	= Olenellus (in part), includes discussion of many of the forms now placed in Mesonacidae
Olenellus Ford [1878, p. 130, footnote]	= Elliptocephala
Olenellus Ford [1881, pp. 250-259]	= Elliptocephala (in part), Mesonacis (in part), and Olenellus (in part)
Olenellus Hall [1862, p. 114]	= Olenellus
Olenellus Holm [1887, pp. 498-499]	= includes many of the forms now referred to the Mesonacidae
Olenellus Lindström [1901, pp. 12-18]	= Elliptocephala

LIST (ARRANGED BY GENERA, SUBGENERA, AND SPECIES) OF THE FORMS NOW PLACED IN THE MESONACIDÆ, AS THEY OCCUR IN THE LITERATURE, WITH THE PRESENT REFERENCE OF EACH—Cont'd

Olenellus Lindström [1901, p. 24]	= Olenellus
Olenellus Marcou [1889, p. 74]	= Olenellus
Olenellus Marcou [1890, p. 362]	= Olenellus
Olenellus Moberg [1899, p. 317]	= Olenellus
Olenellus Peach [1894, pp. 671-673]	= Olenellus
Olenellus Peach and Horne [1892, p. 236]	= Olenellus
Olenellus Pompeckj [1901, pp. 14-17]	= Olenellus
Olenellus Walcott [1886, pp. 162-166]	= Elliptocephala (in part), Olenellus (in part), Callavia (in part), and Peachella (in part)
Olenellus Walcott [1890, pp. 40-41]	= Olenellus
Olenellus Walcott [1891a, pp. 633-635]	= Olenellus (in part) and Callavia (in part)
Olenellus Weller [1900, pp. 50-51]	= Olenellus (in part), discusses genus in broad sense
(Olenellus) [Holmia] Peach [1894, pp. 671-674]	= Holmia (in part) and Callavia (in part)
(Olenellus) [Mesonacis] Peach [1894, pp. 671-674]	= Elliptocephala (in part) and Mesonacis (in part)
Olenellus argentus Walcott (new)	= Olenellus argentus
Olenellus asaphoides Bernard [1894, pp. 415-416 and 423-424; fig. 3, p. 415; figs. 4a-c and 5, p. 416; and fig. 9, p. 423]	= Elliptocephala asaphoides
Olenellus asaphoides Ford [1878, pp. 129-130]	= Elliptocephala asaphoides
Olenellus asaphoides Ford [1881, pp. 250-259, figs. 1-3, p. 251]	= Elliptocephala asaphoides
Olenellus asaphoides Holm [1887, p. 515]	= Elliptocephala asaphoides
Olenellus asaphoides Lesley [1889, p. 489, 10 text figs.]	= Elliptocephala asaphoides
Olenellus asaphoides Lindström [1901, pp. 12-18, text figs. 1-10, p. 13]	= Elliptocephala asaphoides

Olenellus asaphoides Matthew [1891, p. 289 and footnote] .... = Elliptocephala asaphoides
Olenellus asaphoides Walcott [1884, pp. 36-37, pl. 21, figs. 10-12] .... = Elliptocephala asaphoides
Olenellus asaphoides Walcott [1886, pp. 168-170, pl. 17, figs. 3-8 and 10; pl. 20, figs. 3, 3a-b; and pl. 25, fig. 8] .... = Elliptocephala asaphoides
(Olenellus) asaphoides [Mesonacis] Peach [1894, p. 671; text fig. C, p. 673; and pl. 32, fig. 11] ... = Elliptocephala asaphoides
Olenellus bröggeri Bernard [1894, p. 423] .... = Callavia bröggeri
Olenellus bröggeri Walcott [1888, p. 551] .... = Callavia bröggeri
Olenellus callavei Lapworth [1888a, p. 485] .... = Callavia callavei
Olenellus callavei Lapworth [1888b, p. 212] .... = Callavia callavei
Olenellus canadensis Walcott [1908b, p. 242] .... = Olenellus canadensis (in part) and Olenellus gilberti (in part)
Olenellus canadensis Walcott [1908c, p. 215] .... = Olenellus canadensis (in part) and Olenellus gilberti (in part)
Olenellus claytoni Walcott [1908c, p. 189, 6 of section] .... = Olenellus gilberti (in part) and Olenellus claytoni (in part)
Olenellus fremonti Walcott [1908c, p. 187] .... = Olenellus fremonti
Olenellus gigas Peach [1894, p. 666, fig. 1, p. 667] .... = Olenellus gigas
Olenellus gilberti Holm [1887, pp. 514-515] .... = Olenellus gilberti
Olenellus gilberti Lesley [1889, p. 490, whole specimens represented by figs. 1 and 1a] .... = Olenellus gilberti
Olenellus gilberti Lesley [1889, p. 490, fig. 2a and cephalons represented by figs. 1, 1a, 1b, and 1f]. = Olenellus fremonti
Olenellus gilberti McConnell [1887, p. 30D] .... = Wanneria ? gracile
Olenellus gilberti Meek [1874, MS.] .... = Olenellus gilberti
Olenellus gilberti Peach [1894, p. 671, pl. 32, figs. 9 and 10] .... = Olenellus fremonti
Olenellus gilberti Walcott [1884, p. 29, pl. 9, fig. 16a] .... = Olenellus fremonti
Olenellus gilberti Walcott [1884, p. 29, pl. 9, fig. 16, and pl. 21, fig. 13] .... = Callavia ? nevadensis
Olenellus gilberti Walcott [1884, p. 29, pl. 21, fig. 14] .... = Olenellus gilberti
Olenellus gilberti Walcott [1886, pp. 170-180, pl. 18, figs. 1, 1a-b; pl. 19, figs. 2, 2a, 2b, 2k; pl. 20, fig. 4; and pl. 21, figs. 1 and 1a] .... = Olenellus gilberti
Olenellus gilberti Walcott [1886, pp. 170-180, pl. 18, fig. 1c; pl. 19, figs. 2e, 2h, 2i; pl. 20, figs. 1, 1a-i, 1k-m; and pl. 21, figs. 2 and 2a] .... = Olenellus fremonti

LIST (ARRANGED BY GENERA, SUBGENERA, AND SPECIES) OF THE FORMS NOW PLACED IN THE MESONACIDÆ, AS THEY OCCUR IN THE LITERATURE, WITH THE PRESENT REFERENCE OF EACH—Cont'd

Olenellus gilberti Walcott [1886, pp. 170-180, pl. 19, figs. 2c, 2d, 2f, and 2g]	= Callavia ? nevadensis
Olenellus gilberti Walcott [1891a, pl. 84, figs. 1, 1a-c; pl. 85, figs. 1b-d; and pl. 86, fig. 4]	= Olenellus gilberti
Olenellus gilberti Walcott [1891a, pl. 84, figs. 1d and 1f; pl. 85, figs. 1, 1a, and 1f; and pl. 86, figs. 1, 1a-i, 1k-m]	= Olenellus fremonti
Olenellus gilberti Walcott [1891a, pl. 84, figs. 1e and 1g; and pl. 85, figs. 1e and 1g]	= Callavia ? nevadensis
Olenellus gilberti Walcott [1908c, p. 189, 2 of section]	= Olenellus gilberti
Olenellus gilberti White [1874, p. 7]	= Olenellus gilberti
Olenellus gilberti White [1877, pp. 44-46, pl. 2, figs. 3a-e]	= Olenellus gilberti
(Olenellus) gilberti [Olenus] Gilbert [1875, pp. 182-183]	= Olenellus gilberti
Olenellus gilberti var. Walcott (new)	= Olenellus gilberti var.
Olenellus howelli Meek [1874, MS.]	= Olenellus gilberti
Olenellus howelli Walcott [1884, pp. 30-31, pl. 9, figs. 15, 15a-c; and pl. 21, figs. 1-9, 16-17]	= Olenellus fremonti
Olenellus howelli White [1874, p. 8]	= Olenellus gilberti
Olenellus howelli White [1877, pp. 47-48, pl. 2, figs. 4a-b]	= Olenellus gilberti
(Olenellus) howelli [Olenus] Gilbert [1875, p. 183]	= Olenellus gilberti
Olenellus iddingsi Holm [1887, p. 515]	= Peachella iddingsi
Olenellus iddingsi Walcott [1884, p. 28, pl. 9, fig. 12]	= Peachella iddingsi
Olenellus iddingsi Walcott [1886, p. 170, pl. 19, fig. 1]	= Peachella iddingsi
Olenellus iddingsi Walcott [1891a, p. 636, pl. 84, fig. 2]	= Peachella iddingsi
Olenellus intermedius Peach [1894, pp. 666-668, pl. 32, fig. 7]	= Olenellus lapworthi
Olenellus kjerulfi Brögger [1878, p. 44]	= Holmia kjerulfi
Olenellus kjerulfi Holm [1887, pp. 499-512]	= Holmia kjerulfi
Olenellus kjerulfi Koken [1896, p. 7, fig. 2]	= Holmia kjerulfi
Olenellus kjerulfi Linnarsson [1883, pp. 18-20, pl. 3, figs. 12-17]	= Holmia kjerulfi
Olenellus (?) kjerulfi Matthew [1886, pp. 472-473]	= Holmia kjerulfi
(Olenellus) kjerulfi [Holmia] Peach [1894, p. 671, pl. 32, fig. 12]	= Holmia kjerulfi

Olenellus lapworthi Peach [1894, pp. 662-664, pl. 29, figs. 1, 2, and 2a; pl. 30, fig. 7; and pl. 32, fig. 8]	= Olenellus lapworthi
Olenellus lapworthi Peach and Horne [1892, pp. 236-241, pl. 5, figs. 1-11]	= Olenellus lapworthi
Olenellus lapworthi elongatus Peach [1894, p. 664, pl. 29, figs. 3-6]	= Olenellus lapworthi
Olenellus logani Walcott (new)	= Olenellus logani
Olenellus lundgreni Moberg [1892, p. 3]	= Holmia lundgreni
Olenellus mickwitzi Schmidt [1888, pp. 13-19, pl. 1, figs. 1-25]	= Mesonacis mickwitzi
Olenellus mickwitzi Schmidt [1889, pp. 191-195, 10 text figs., p. 193]	= Mesonacis mickwitzi
Olenellus reticulatus Peach [1894, pp. 665-666, text fig. A, p. 673; pl. 30, figs. 1-6, 8-14; and pl. 31, figs. 1-7]	= Olenellus reticulatus
Olenellus thompsoni Billings [1865, p. 11]	= Pædeumias transitans
Olenellus thompsoni Cole [1892, p. 343]	= Olenellus thompsoni
Olenellus thompsoni Ford [1881, fig. 12, p. 258]	= Olenellus thompsoni
Olenellus thompsoni Frech [1897, pl. 1a, fig. 7]	= Olenellus thompsoni
Olenellus thompsoni Hall [1862b, p. 114]	= Olenellus thompsoni
Olenellus thompsoni Holm [1887, p. 514]	= Olenellus thompsoni
Olenellus thompsoni Lesley [1889, p. 491, 3 text figs.]	= Olenellus thompsoni
Olenellus thompsoni Lindström [1901, p. 12]	= Olenellus thompsoni
Olenellus thompsoni Moberg [1899, pp. 314 and 317, pl. 13, fig. 2]	= Olenellus thompsoni
Olenellus thompsoni Walcott [1886, pp. 167-168, pl. 17, fig. 1]	= Olenellus thompsoni crassimarginatus
Olenellus thompsoni Walcott [1886, pp. 167-168, pl. 17, figs. 2, 4, and 9; pl. 22, fig. 1; and pl. 23, fig. 1]	= Olenellus thompsoni
Olenellus thompsoni Walcott [1891a, pl. 82, figs. 1 and 1a; and pl. 83, figs. 1 and 1a]	= Olenellus thompsoni
Olenellus thompsoni Walcott [1891a, pl. 83, fig. 1b]	= Olenellus thompsoni crassimarginatus
Olenellus thompsoni ? Weller [1900, pp. 49-51, pl. 1, figs. 9-10]	= Pædeumias transitans
Olenellus thompsoni Whitfield [1884, pp. 151-153, pl. 15, fig. 1]	= Pædeumias transitans
Olenellus thompsoni crassimarginatus Walcott (new)	= Olenellus thompsoni crassimarginatus

LIST (ARRANGED BY GENERA, SUBGENERA, AND SPECIES) OF THE FORMS NOW PLACED IN THE MESONACIDÆ, AS THEY OCCUR IN THE LITERATURE, WITH THE PRESENT REFERENCE OF EACH—Cont'd

Olenellus torelli Moberg [1892, p. 3]	= Mesonacis torelli
Olenellus vermontana Billings [1865, p. 11]	may = Mesonacis vermontana
Olenellus vermontana Hall [1862b, p. 114]	= Mesonacis vermontana
Olenellus vermontana Whitfield [1884, pp. 152-153, pl. 15, figs. 2-4]	= Pædeumias transitans
Olenellus vermontanus Ford [1881, fig. 13, p. 258]	= Mesonacis vermontana
Olenellus vermontanus Holm [1887, pp. 515-516]	= Mesonacis vermontana
Olenellus walcotti Walcott [1891a, pp. 636-637, pl. 88, fig. 2]	= Olenellus ?? walcotti
Olenellus walcotti Grabau [1900, p. 669]	= Olenellus ?? walcotti
Olenellus sp. Burr [1900, p. 45]	= Callavia burri
Olenellus sp. Grabau [1900, pp. 665-667, pl. 34, figs. 1a-b]	= Callavia burri
Olenellus sp. Moberg [1892, p. 4]	= Olenellus ?, sp. undt.
Olenellus ? sp. n. Moberg [1899, pp. 338-339, pl. 15, figs. 18-19]	= Olenellus ?, sp. undt.
Olenellus ? sp. undt. Walcott (new)	= Olenellus ?, sp. undt.
Olenellus (Elliptocephalus) Ford [1877, pp. 265-272]	= Elliptocephala
Olenellus (Elliptocephalus) asaphoides Ford [1877, pp. 265-272, pl. 4, figs. 1-10]	= Elliptocephala asaphoides
Olenellus (Georgiellus) Pompeckj [1901, p. 16]	= Elliptocephala
Olenellus (Georgiellus) asaphoides Pompeckj [1901, p. 16]	= Elliptocephala asaphoides
Olenellus (Holmia) Cole [1892, fig. 3, p. 343]	= Holmia
Olenellus (Holmia) bröggeri Burr [1900, pp. 43-44]	= Callavia crosbyi
Olenellus (Holmia) bröggeri Grabau [1900, pp. 662-664, pl. 33, figs. 1a-j]	= Callavia crosbyi
Olenellus (Holmia) brœggeri Pompeckj [1901, pl. 1, fig. 10]	= Callavia bröggeri
Olenellus (Holmia) bröggeri Walcott [1891a, pp. 638-640, pl. 91, fig. 1; pl. 92, figs. 1, 1a-h]	= Callavia bröggeri
Olenellus (Holmia) calevi Walcott [1891a, p. 635]	= Callavia callavei
Olenellus (Holmia) callavei Cole [1892, pp. 344 and 345]	= Callavia callavei
Olenellus (Holmia) callavei Lapworth [1891b, pp. 530-536, pl. 14, figs. 1-25, and pl. 15]	= Callavia callavei
Olenellus (Holmia ?) cartlandi Raw [1909, MS.]	= Callavia cartlandi
Olenellus (Holmia) kjerulfi Cole [1892, p. 343, fig. 3]	= Holmia kjerulfi

Olenellus (Holmia) kjerulfi Frech [1897, pl. 1a, fig. 13] = Holmia kjerulfi
Olenellus (Holmia) kjerulfi Walcott [1891a, p. 635, pl. 86, fig. 2, and pl. 93, fig. 2] = Holmia kjerulfi
Olenellus (Holmia) walcottanus Wanner [1901, pp. 267-269, pl. 31, figs. 1 and 2; pl. 32, figs. 1-4] = Wanneria walcottanus
Olenellus (Mesonacis) Cole [1892, fig. 3, p. 343] = Mesonacis
Olenellus (Mesonacis) Walcott [1891a, p. 637] = Elliptocephala (in part) and Mesonacis (in part)
Olenellus (Mesonacis) asaphoides Beecher [1895, p. 176, figs. 6-8, p. 175] = Elliptocephala asaphoides
Olenellus (Mesonacis) asaphoides Burr [1900, p. 45] = Callavia crosbyi
Olenellus (Mesonacis) asaphoides ? Grabau [1900, pp. 667-669, pl. 34, figs. 2a-b] = Callavia crosbyi
Olenellus (Mesonacis) asaphoides Walcott [1890, p. 41] = Elliptocephala asaphoides
Olenellus (Mesonacis) asaphoides Walcott [1891a, pp. 637-638, pl. 86, figs. 3, 3a-b; pl. 88, figs. 1, 1a-g; pl. 89, figs. 1 and 1a; and pl. 90, figs. 1 and 1a] = Elliptocephala asaphoides
Olenellus (Mesonacis) asaphoides Clarke and Ruedemann [1903, pp. 730-732] = Elliptocephala asaphoides
Olenellus (Mesonacis) bröggeri Walcott [1889, pp. 378-380] = Callavia bröggeri
Olenellus (Mesonacis) bröggeri Walcott [1890, p. 41] = Callavia bröggeri
Olenellus (Mesonacis) mickwitzi Frech [1897, pl. 1a, fig. 8] = Mesonacis mickwitzi
Olenellus (Mesonacis) mickwitzi Walcott [1891a, p. 634, pl. 93, fig. 1] = Mesonacis mickwitzi
Olenellus (Mesonacis) vermontana Cole [1892, p. 340 and 341, fig. 2, p. 343] = Mesonacis vermontana
Olenellus (Mesonacis) vermontana Walcott [1891a, p. 637, pl. 87, figs. 1, 1a-b] = Mesonacis vermontana
Olenellus (Olenelloides) Peach [1894, pp. 668-669 and 671-674] = Olenelloides
Olenellus (Olenelloides) armatus Peach [1894, pp. 669-670, pl. 32, figs. 1-6] = Olenelloides armatus
Olenellus (Olenus) asaphoides Ford [1871a, p. 33] = Elliptocephala asaphoides
Olenellus (Olenus) asaphoides Ford [1871b, p. 210] = Elliptocephala asaphoides
Olenus Hall [1847, p. 256, footnote] = Elliptocephala
Olenus Hall [1859a, p. 59] = Olenellus
Olenus Hall [1859b, p. 525] = Olenellus
Olenus asaphoides Fitch [1849, p. 865] = Elliptocephala asaphoides
Olenus asaphoides Hall [1847, pp. 256-257, pl. 67, figs. 2a-c] = Elliptocephala asaphoides
(Olenus) asaphoides [Olenellus] Ford [1871a, p. 33] = Elliptocephala asaphoides
(Olenus) asaphoides [Olenellus] Ford [1871b, p. 210] = Elliptocephala asaphoides

LIST (ARRANGED BY GENERA, SUBGENERA, AND SPECIES) OF THE FORMS NOW PLACED IN THE MESONACIDÆ, AS THEY OCCUR IN THE LITERATURE, WITH THE PRESENT REFERENCE OF EACH—Cont'd

Olenus thompsoni Hall [1859a, p. 59, fig. 1, p. 60]	= Olenellus thompsoni
Olenus thompsoni Hall [1859b, pp. 525-526, fig., p. 526]	= Olenellus thompsoni
Olenus vermontana Hall [1859a, pp. 60-61, fig. 2, p. 60]	= Mesonacis vermontana
Olenus vermontana Hall [1859b, p. 527, text fig.]	= Mesonacis vermontana
Olenus (Olenellus) gilberti Gilbert [1875, pp. 182-183]	= Olenellus gilberti
Olenus (Olenellus) howelli Gilbert [1875, p. 183]	= Olenellus gilberti
Pædeumias Walcott (new)	= Pædeumias
Pædeumias transitans Walcott (new)	= Pædeumias transitans
Paradoxides Emmons [1860, p. 88]	= Olenellus
Paradoxides Ford [1878, p. 130, footnote]	= Holmia (in part) and Elliptocephala (in part)
Paradoxides asaphoides Barrande [1861, pp. 273-276, pl. 5, figs. 4-5]	= Elliptocephala asaphoides
Paradoxides asaphoides Emmons [1860, p. 87, legend of fig. 70]	= Olenellus thompsoni
(Paradoxides) asaphoides [Eliptocephalus] Emmons [1860, p. 280]	= Olenellus thompsoni
Paradoxides brachycephalus Emmons [1860, first edition, p. 87]	= Olenellus thompsoni
Paradoxides kjerulfi Ford [1878, p. 130, footnote]	= Holmia kjerulfi
Paradoxides ? kjerulfi Ford [1881, pp. 255-258, fig. 10, p. 256]	= Holmia kjerulfi
Paradoxides kjerulfi Kjerulf [1873, p. 83, figs. 1-5]	= Holmia kjerulfi
Paradoxides kjerulfi Linnarsson [1871, pp. 790-792, pl. 16, figs. 1-3]	= Holmia kjerulfi
Paradoxides kjerulfi Walcott [1886, p. 178, pl. 20, fig. 2]	= Holmia kjerulfi
Paradoxides macrocephalus Barrande [1861, pp. 276-277, pl. 5, fig. 7]	= Olenellus thompsoni
Paradoxides macrocephalus Emmons [1860, p. 87 and p. 280]	= Olenellus thompsoni
Paradoxides thompsoni Barrande [1861, p. 276, pl. 5, fig. 6]	= Olenellus thompsoni
Paradoxides thompsoni Billings [1861, p. 11]	= Pædeumias transitans
Paradoxides thompsoni Emmons [1860, p. 280]	= Olenellus thompsoni
Paradoxides vermontana Barrande [1861, pp. 277-278, pl. 5, fig. 8]	= Mesonacis vermontana
Paradoxides vermontana Billings [1861, p. 11]	may = Mesonacis vermontana

Paradoxides vermonti Emmons [1860, p. 280, note A]	= Mesonacis vermontana
Paradoxides walcotti Shaler and Foerste [1888, pp. 36-37, pl. 2, fig. 12]	= Olenellus ?? walcotti
Paradoxides (Gen. ?) kjerulfi Matthew [1888, pp. 75-76]	= Holmia kjerulfi
Peachella Walcott (new)	= Peachella
reticulatus [Olenellus] Peach [1894, pp. 665-666, text fig. A, p. 673; pl. 30, figs. 1-6, 8-14; and pl. 31, figs. 1-7]	= Olenellus reticulatus
rowei [Holmia] Walcott [1908c, p. 186, 1d and 2j of section]	= not specifically identified
rowei [Holmia] Walcott [1908c, pp. 187 and 188, 3 of section]	= Wanneria ? gracile
rowei [Holmia] Walcott [1908c, p. 189, 3 of section]	= Olenellus argentus (in part) and Olenellus gilberti (in part)
rowei [Holmia] Walcott [1908c, p. 189, 12 of section]	= Holmia rowei
Schmidtia Bals-Criv	= Protozoan
Schmidtia Moberg [1899, p. 319 and footnote]	= Mesonacis
Schmidtia Volborth [1860]	= Brachiopod
(Schmidtia) [Elliptocephalus] Marcou [1890, p. 363]	= Mesonacis (in part) and Zacanthoides (in part)
Schmidtia mickwitzi Moberg [1899, pp. 319-320, pl. 13, figs. 5a-c]	= Mesonacis mickwitzi
(Schmidtia) mickwitzi [Elliptocephalus] Marcou [1890, p. 363]	= Mesonacis mickwitzi
Schmidtia ? torelli Moberg [1899, pp. 330-338, pl. 15, figs. 1-17]	= Mesonacis torelli
(Schmidtia) vermontana [Elliptocephalus] Marcou [1890, p. 363]	= Mesonacis vermontana
Schmidtiellus Moberg, Moberg and Segerberg [1906, p. 35, footnote]	= Mesonacis
Schmidtiellus mickwitzi Moberg, Moberg and Segerberg [1906, p. 35, footnote]	= Mesonacis mickwitzi
thompsoni [Barrandia] Hall [1860, pp. 115-116, fig., p. 116]	= Olenellus thompsoni
thompsoni [Barrandia] Hall [1861, pp. 369-370]	= Olenellus thompsoni
thompsoni [Barrandia] Hall [1862a, pl. 13, fig. 1]	= Olenellus thompsoni
thompsoni [Elliptocephala] Miller [1889, p. 546, fig. 1003]	= Olenellus thompsoni
thompsoni [Olenellus] Billings [1865, p. 11]	= Olenellus thompsoni
thompsoni [Olenellus] Cole [1892, p. 343]	= Pædeumias transitans
thompsoni [Olenellus] Ford [1881, fig. 12, p. 258]	= Olenellus thompsoni
thompsoni [Olenellus] Frech [1897, pl. 1a, fig. 7]	= Olenellus thompsoni
thompsoni [Olenellus] Hall [1862b, p. 114]	= Olenellus thompsoni

LIST (ARRANGED BY GENERA, SUBGENERA, AND SPECIES) OF THE FORMS NOW PLACED IN THE MESONACIDÆ, AS THEY OCCUR IN THE LITERATURE, WITH THE PRESENT REFERENCE OF EACH—Cont'd

thompsoni [Olenellus] Holm [1887, p. 514]	= Olenellus thompsoni
thompsoni [Olenellus] Lesley [1889, p. 491, 3 text figs.]	= Olenellus thompsoni
thompsoni [Olenellus] Lindström [1901, p. 12]	= Olenellus thompsoni
thompsoni [Olenellus] Moberg [1899, pp. 314 and 317, pl. 13, fig. 2]	= Olenellus thompsoni
thompsoni [Olenellus] Walcott [1886, pp. 167-168, pl. 17, fig. 1]	= Olenellus thompsoni crassimarginatus
thompsoni [Olenellus] Walcott [1886, pp. 167-168, pl. 17, figs. 2, 4, and 9; pl. 22, fig. 1; and pl. 23, fig. 1]	= Olenellus thompsoni
thompsoni [Olenellus] Walcott [1891a, pl. 82, figs. 1 and 1a; and pl. 83, figs. 1 and 1a]	= Olenellus thompsoni
thompsoni [Olenellus] Walcott [1891a, pl. 83, fig. 1b]	= Olenellus thompsoni crassimarginatus
thompsoni ? [Olenellus] Weller [1900, pp. 49-51, pl. 1, figs. 9-10]	= Pædeumias transitans
thompsoni [Olenellus] Whitfield [1884, pp. 151-153, pl. 15, fig. 1]	= Pædeumias transitans
thompsoni [Olenus] Hall [1859a, p. 59, fig. 1, p. 60]	= Olenellus thompsoni
thompsoni [Olenus] Hall [1859b, pp. 525-526, fig., p. 526]	= Olenellus thompsoni
thompsoni [Paradoxides] Barrande [1861, p. 276, pl. 5, fig. 6]	= Olenellus thompsoni
thompsoni [Paradoxides] Billings [1861, p. 11]	= Pædeumias transitans
thompsoni [Paradoxides] Emmons [1860, p. 280]	= Olenellus thompsoni
thompsoni crassimarginatus [Olenellus] Walcott (new)	= Olenellus thompsoni crassimarginatus
torelli [Olenellus] Moberg [1892, p. 3]	= Mesonacis torelli
torelli [Schmidtia ?] Moberg [1899, pp. 330-338, pl. 15, figs. 1-17]	= Mesonacis torelli
transitans [Pædeumias] Walcott (new)	= Pædeumias transitans
vermontana [Barrandia] Hall [1860, p. 117, text fig.]	= Mesonacis vermontana
vermontana [Barrandia] Hall [1861, p. 370]	= Mesonacis vermontana (in part) and Pædeumias transitans (in part)

vermontana [Barrandia] Hall [1862a, pl. 13, fig. 2] ... = Mesonacis vermontana
vermontana [Barrandia] Hall [1862a, pl. 13, figs. 4 and 5] ... = Pædeumias transitans
vermontana [Elliptocephalus (Schmidtia)] Marcou [1890, p. 363] ... = Mesonacis vermontana
vermontana [Mesonacis] Moberg [1899, p. 318, pl. 13, fig. 4] ... = Mesonacis vermontana
vermontana [Olenellus] Billings [1865, p. 11] ... may = Mesonacis vermontana
vermontana [Olenellus] Hall [1862b, p. 114] ... = Mesonacis vermontana
vermontana [Olenellus] Whitfield [1884, pp. 152-153, pl. 15, figs. 2-4] ... = Pædeumias transitans
vermontana [Olenellus (Mesonacis)] Cole [1892, p. 340 and 341, fig. 2, p. 343] ... = Mesonacis vermontana
vermontana [Olenellus (Mesonacis)] Walcott [1891a, p. 637, pl. 87, figs. 1, 1a-b] ... = Mesonacis vermontana
vermontana [Olenus] Hall [1859a, pp. 60-61, fig. 2, p. 60] ... = Mesonacis vermontana
vermontana [Olenus] Hall [1859b, p. 527, text fig.] ... = Mesonacis vermontana
vermontana [Paradoxides] Barrande [1861, pp. 277-278, pl. 5, fig. 8] ... = Mesonacis vermontana
vermontana [Paradoxides] Billings [1861, p. 11] ... may = Mesonacis vermontana
vermontanus [Mesonacis] Walcott [1885, pp. 328-330, figs. 1 and 2, p. 329] ... = Mesonacis vermontana
vermontanus [Mesonacis] Walcott [1886, pp. 158-162, pl. 24, figs. 1, 1a-b] ... = Mesonacis vermontana
vermontanus [Olenellus] Ford [1881, fig. 13, p. 258] ... = Mesonacis vermontana
vermontanus [Olenellus] Holm [1887, pp. 515-516] ... = Mesonacis vermontana
vermonti [Paradoxides] Emmons [1860, p. 280, note A] ... = Mesonacis vermontana
walcottanus [Olenellus (Holmia)] Wanner [1901, pp. 267-269, pl. 31, figs. 1 and 2; pl. 32, figs. 1-4] ... = Wanneria walcottanus
walcotti [Olenellus] Grabau [1900, p. 669] ... = Olenellus ?? walcotti
walcotti [Olenellus] Walcott [1891a, pp. 636-637, pl. 88, fig. 2] ... = Olenellus ?? walcotti
walcotti [Paradoxides] Shaler and Foerste [1888, pp. 36-37, pl. 2, fig. 12] ... = Olenellus ?? walcotti
Wanneria Walcott (new) ... = Wanneria
Wanneria ? gracile Walcott (new) ... = Wanneria ? gracile
Wanneria halli Walcott (new) ... = Wanneria halli
weeksi [Holmia] Walcott [1908c, p. 187, 2j of section] ... = Olenellus fremonti
weeksi [Holmia] Walcott [1908c, p. 189, 3 of section] ... = Wanneria ? gracile
weeksi [Holmia] Walcott [1908c, p. 189, 6 of section] ... = Olenellus fremonti
weeksi [Holmia] Walcott [1908c, p. 189, 11 of section] ... = not specifically identified
weeksi [Holmia] Walcott [1908c, p. 189, 12 of section] ... = Nevadia weeksi
weeksi [Nevadia] Walcott (new) ... = Nevadia weeksi

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DESCRIPTION OF PLATE 23

PAGE

Nevadia weeksi, new genus and new species (See pl. 44) 257

FIG. 1. A large specimen of the dorsal shield preserving nearly the entire thorax and a portion of the cephalon. The cephalon has been restored in outline from specimens represented by figs. 2 and 3. Two-thirds natural size. U. S. National Museum, Catalogue No. 56792*a*.

2. A nearly perfect individual showing fifteen thoracic segments in the anterior portion of the thorax and eleven in the posterior portion. Natural size. U. S. National Museum, Catalogue No. 56792*b*.

The difference between the posterior portion and anterior portion of the thoracic segments is also shown by fig. 4.

3. A specimen that has been slightly distorted by compression, showing the cephalon and a few thoracic segments. Natural size. U. S. National Museum, Catalogue No. 56792*c*.

4. Posterior portion of the thorax. This shows five segments of the anterior portion and ten segments of the posterior portion of the thorax. Natural size. U. S. National Museum, Catalogue No. 56792*d*.

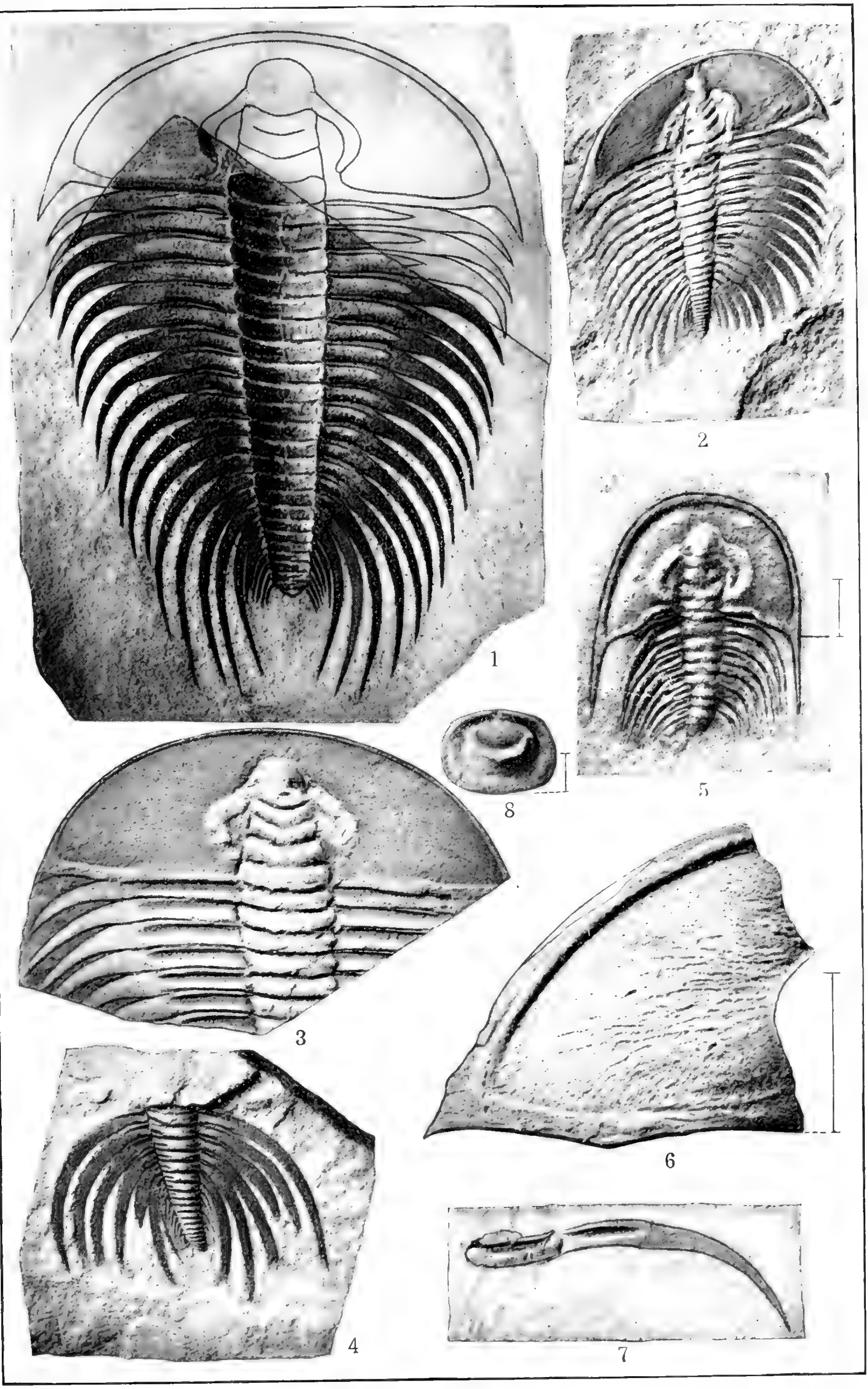
5. Cephalon and portion of the thorax. $\times 4$. This represents the smallest specimen found of this species. U. S. National Museum, Catalogue No. 56792*e*.

6. Enlargement of the lateral cheeks of a cephalon between the eye and the outer anterior and posterior borders. This illustrates very perfectly the venation extending outward from the base of the eye lobe. $\times 2$. U. S. National Museum, Catalogue No. 56792*f*.

7. Portion of a thoracic segment illustrating the central axis, the pleural lobes and extension. Natural size. U. S. National Museum, Catalogue No. 56792*g*.

8. Pygidium ($\times 2$) that is associated with specimens of this species and *Holmia rowei* [pl. 29]. U. S. National Museum, Catalogue No. 56792*h*.

The specimens represented by figs. 1-8 are from locality (1*f*), 16 miles south of Silver Peak, Nevada.



LOWER CAMBRIAN TRILOBITES

DESCRIPTION OF PLATE 24

PAGE

Elliptocephala asaphoides Emmons (See pls. 25 and 44) 269

FIG. 1. A nearly entire specimen from the type locality (35*b*), one mile west of North Greenwich, Washington County, New York. The spines on the five posterior thoracic segments have been restored from another specimen. Two-thirds natural size. U. S. National Museum, Catalogue No. 18350*a*.

2. Pygidium and seven posterior thoracic segments of the specimen represented by fig. 1 but without the five dorsal spines. Natural size. U. S. National Museum, Catalogue No. 18350*a*.

Figs. 1 and 2 are copied from Walcott, 1891*a*, pl. 89, figs. 1 and 1*a*.

3. A small, nearly entire dorsal shield with the third thoracic segment prolonged into long spines. × 4. Collection New York State Museum, Albany.

4. A dorsal shield 8 mm. in length with 13 segments. Whether the last segment (?) is the pygidium or a turned in segment cannot be determined. × 3. Collection New York State Museum, Albany.

5. Cephalon and 13 segments of young individual in which the third thoracic segment is not prolonged beyond the others. × 2. The glabella is broadened and the entire cephalon shortened by compression and crushing. Collection New York State Museum, Albany.

Figures 3, 4, and 5 are copied from Walcott, 1891*a*, pl. 88, figs. 1*b*, 1*c*, and 1*d*, respectively.

6. Cephalon 5 mm. in length that was used as the base for fig. 1*f*, pl. 88 of Walcott [1891*a*]. × 2. Restored to the right of the line crossing the drawing. Locality (38) near South Granville, Washington County, New York. U. S. National Museum, Catalogue No. 15413*a*.

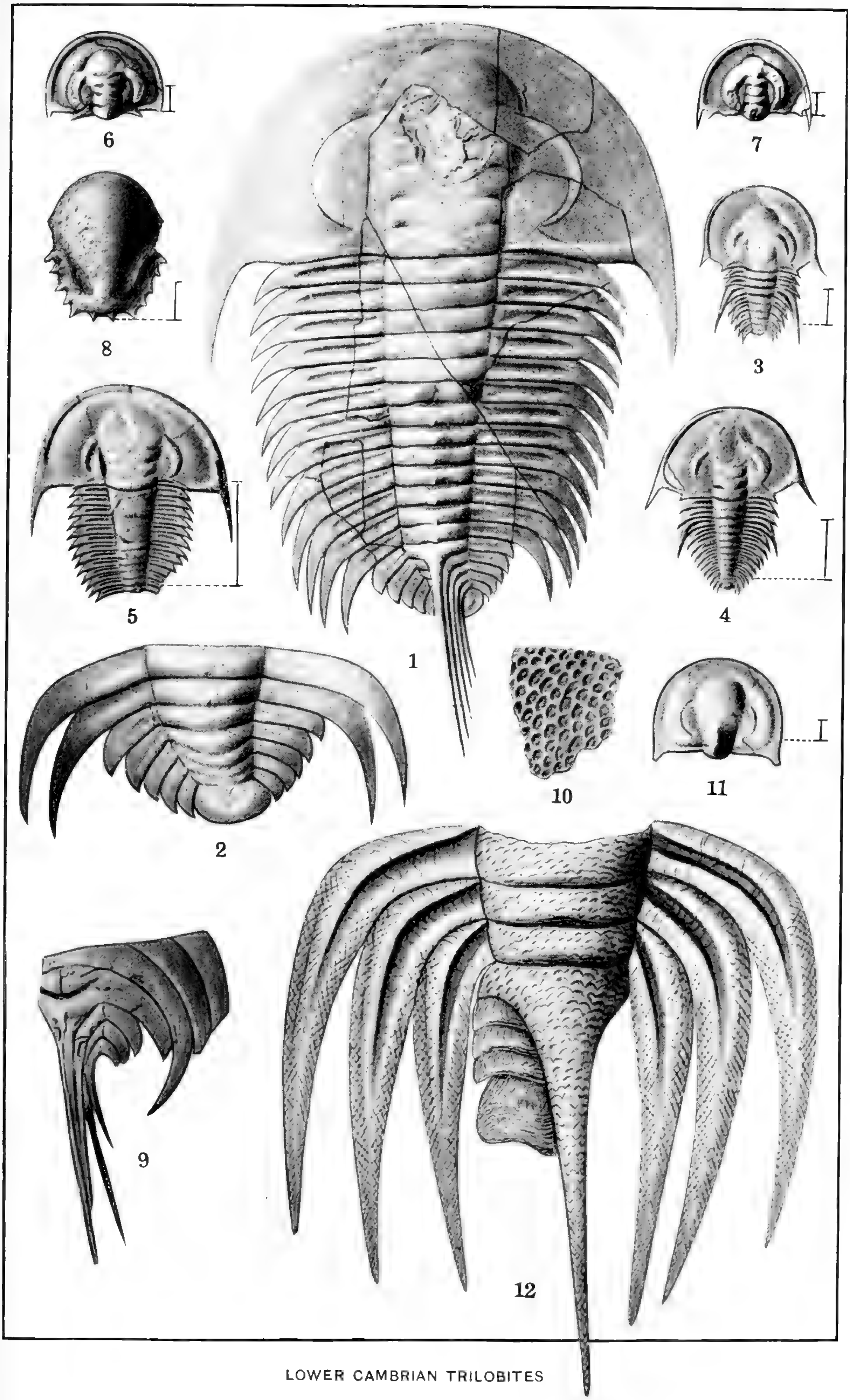
7. A cephalon 3 mm. in length with glabella much like that of fig. 6. × 3. Locality (38*a*), near North Granville, Washington County, New York. U. S. National Museum, Catalogue No. 15413*b*.

8. Form of hypostoma associated with this species at several localities. × 4. This specimen is from locality (33), in the township of Greenwich, Washington County, New York. U. S. National Museum, Catalogue No. 15413*c*.

Figure 8 is drawn from the specimen illustrated by Walcott, 1891*a*, pl. 88, fig. 1*g*.

9. A fragment preserving four of the posterior spine bearing thoracic segments. Natural size. Locality (35*b*), near North Greenwich, Washington County, New York. U. S. National Museum, Catalogue No. 18350*b*.

This figure is copied from Walcott, 1891*a*, pl. 90, fig. 1*a*.



LOWER CAMBRIAN TRILOBITES

Elliptocephala asaphoides Emmons (continued): PAGE

10. Enlargement of the reticulated surface of a portion of the outer cheek of an old and large individual. × 6. Locality (27), near Troy, Rensselaer County, New York. U. S. National Museum, Catalogue No. 15413*d*.

Figure 10 is copied from Walcott, 1886, pl. 25, fig. 8.

Olenellus ?? walcotti (Shaler and Foerste) 341

FIG. 11. Type specimen from locality (326*d*) at North Attleborough, Massachusetts. The glabella is crushed so as to make it narrow at the base.

This specimen was first figured by Shaler and Foerste, 1888, pl. 2, fig. 12; it is redrawn in fig. 11 of this paper.

Pædeumias transitans, new genus and new species (See pls. 25, 32, 33, 34, 41, and 44) 304

FIG. 12. Enlargement of the seven posterior segments and pygidium of the specimen represented by fig. 1, pl. 33. This clearly shows the difference in the surface sculpture of the *Olenellus* thoracic segments and that of the three *Pædeumias* rudimentary segments and pygidium. × 3. U. S. National Museum, Catalogue No. 56808*a*.

DESCRIPTION OF PLATE 25

PAGE

Elliptocephala asaphoides Emmons (See pls. 24 and 44) 269

FIG. 1. A young stage (Paraprotaspis) in which the pygidium is outlined and the genal and intergenal spines united. × 16.

2. Cephalon with the genal and intergenal spines slightly separated. × 10.

3. Cephalon with the genal and intergenal spines widely separated but with the genal angles carried slightly forward. × 10. See figs. 3 and 4, pl. 30.

4. Cephalon with transverse posterior margin and normal form of genal spines. × 7.

5. Cephalon with more strongly developed glabella, otherwise much like fig. 4. × 7.

6. Cephalon with short intergenal spines and strongly marked glabella. × 5.

7. Cephalon much like that of fig. 5, but without intergenal spine. × 7.

8. Usual form of fully developed cephalon. × 2.

The above described figs. 1 to 8 were drawn for me by Mr. S. W. Ford from material in his collection obtained from the vicinity of the City of Troy, New York. The drawings are somewhat diagrammatic, but they serve to illustrate progressive development of the form of the cephalon. The Ford collection is now at the New York State Museum in Albany.

Our fig. 9 represents a somewhat younger stage than Ford's fig. 1; fig. 10 corresponds to Ford's fig. 2.

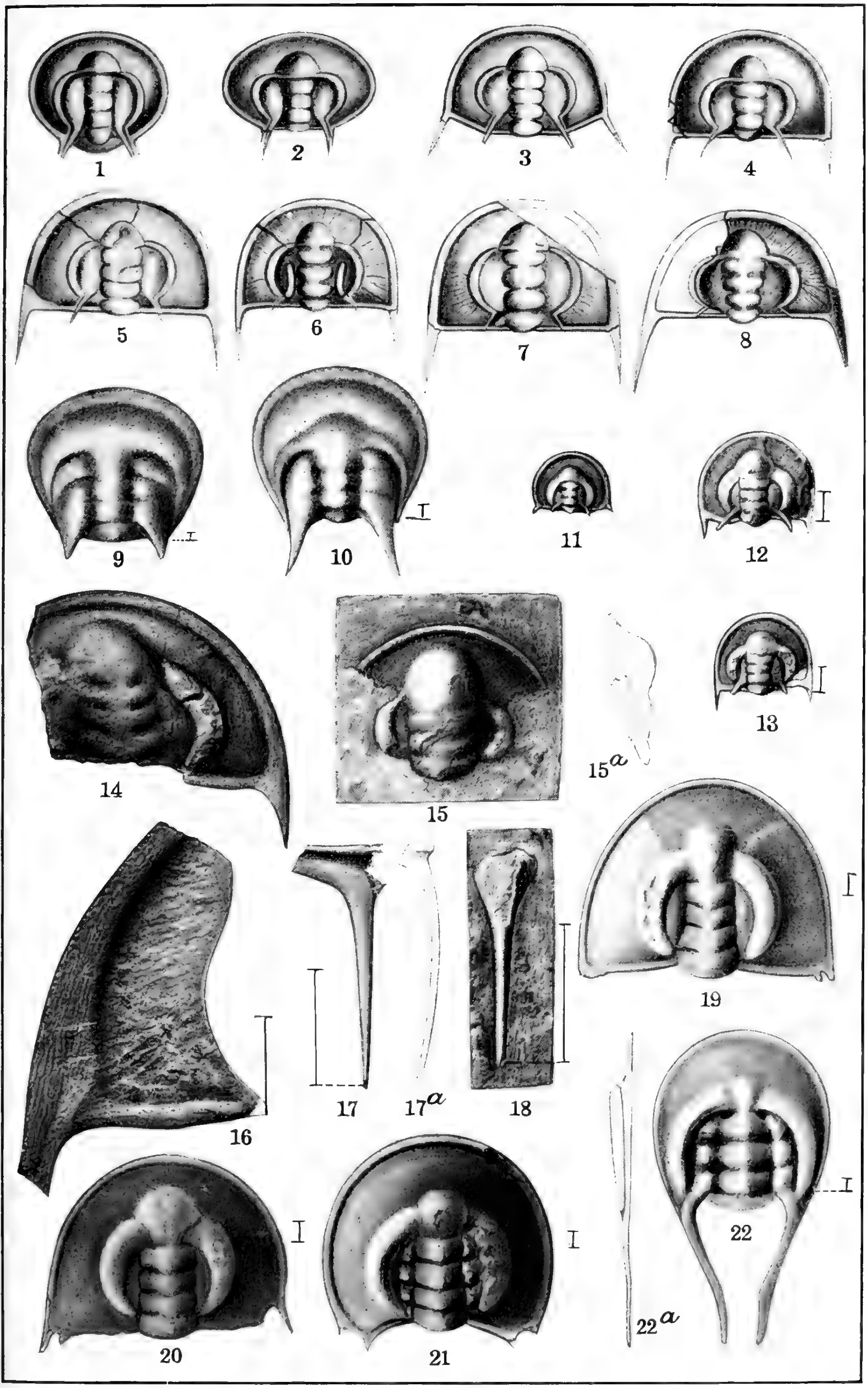
9. The youngest stage (Paraprotaspis) of growth of this species observed. × 25. Length four-fifths of one millimeter. U. S. National Museum, Catalogue No. 15413*e*.

10. A cephalon 1.75 mm. in length. × 15. U. S. National Museum, Catalogue No. 15413*f*.

Figures 9 and 10 are drawn from the same specimens as those illustrated by Walcott, 1886, pl. 17, figs. 5 and 6, respectively. The specimens are both from locality (27), near Troy, Rensselaer County, New York.

11. A cephalon 2 mm. in length that is slightly more advanced in development than fig. 2. × 10. This cephalon comes in between figs. 2 and 3 of the Ford series. Locality (29*a*), near Schodack Landing, Rensselaer County, New York. U. S. National Museum, Catalogue No. 15413g.

12. A cephalon 4 mm. in length with glabella expanded toward its anterior lobe. × 3. Compare with fig. 7, pl. 24, which has a very narrow glabella at its anterior lobe. This is about the same stage as fig. 5 of Ford's series. Locality (27), near Troy, Rensselaer County, New York. U. S. National Museum, Catalogue No. 15413*h*.



LOWER CAMBRIAN TRILOBITES

Elliptocephala asaphoides Emmons (continued): PAGE

13. A small convex cephalon. × 3. Locality (38*a*), near North Granville, Washington County, New York. U. S. National Museum, Catalogue No. 15413*i*.

14. A large flattened cephalon from the limestone in locality (36), 3.5 miles north of Cambridge, Washington County, New York. This approaches in form the specimens from the shale at Greenwich [pl. 24, fig. 1]. Natural size. U. S. National Museum, Catalogue No. 15413*j*.

15. Top and side view of a somewhat compressed cephalon in limestone for comparison with the cephalon of fig. 1, pl. 24, which is flattened in the shale. Natural size. Locality (45*b*), near Low Hampton, Washington County, New York. U. S. National Museum, Catalogue No. 15413*k*.

16. Marginal borders, base of genal spine, and portion of cheek showing surface markings. × 3. Locality (29*a*), near Schodack Landing, Rensselaer County, New York. U. S. National Museum, Catalogue No. 15414*a*.

17 and 17*a*. Top and side view of a thoracic spine occurring in limestone. × 2. Locality (38*a*), North Granville, Washington County, New York. U. S. National Museum, Catalogue No. 15413*l*.

18. Thoracic spine. × 1.5. From locality (27), near Troy, Rensselaer County, New York. U. S. National Museum, Catalogue No. 15413*m*.

This spine was illustrated as the telson of this species by Walcott, 1886, pl. 17, fig. 3.

Pædeumias transitans, new genus and new species (See pls. 24, 32, 33, 34, 41, and 44) 305

FIGS. 19, 20, and 21. Small cephalons showing genal and intergenal spines, cylindrical glabella, large eye lobes, and in fig. 21 the rounding-in of the genal angles. No. 20, × 9; No. 21, × 8; and No. 22, × 13. U. S. National Museum, Catalogue Nos. 56809*a*, 56809*b*, and 56809*c*, respectively.

22. Cephalon with strong protaspis characters. The genal and intergenal spines are practically merged into single spines and the frontal lobe of the glabella nearly merged into the eye lobes. × 30. U. S. National Museum, Catalogue No. 56809*d*.

The genal and intergenal spines in the young cephalons of *Elliptocephala asaphoides* have the same tendency as those of this species [see pl. 25, figs. 9 and 10].

The specimens illustrated by figs. 20-22 are from locality (56*c*), near Helena, Shelby County, Alabama.

DESCRIPTION OF PLATE 26

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Mesonacis vermontana (Hall) (See pl. 44) 264

FIG. 1. An entire dorsal shield from the type locality (25) at Georgia, Vermont, showing 14 thoracic segments of the *Olenellus* type, the spine bearing segment, and ten segments of the *Mesonacis* type. Natural size. U. S. National Museum, Catalogue No. 15399*a*.

2. Posterior portion of the specimen represented in fig. 1.

The specimen represented by figs. 1 and 2 has been figured by Walcott [1885, figs. 1 and 2, p. 329; 1886, pl. 24, figs. 1, 1*a-b;* and 1891*a,* pl. 87, figs. 1, 1*a-b*].

3. Pygidium, ten *Mesonacis* thoracic segments, the spine bearing, and two *Olenellus*-like segments, of a broad form of *Mesonacis vermontana* 6 cm. in length. × 2. This is very much like the posterior portion of fig. 1. Same locality (25) as fig. 1. U. S. National Museum, Catalogue No. 15399*b*.

Mesonacis ? mickwitzi (Schmidt) 262

FIG. 4. Portion of the thorax with seven segments in advance of the spine bearing segment and five between the latter and the pygidium.

This figure is a copy of the figure given by Schmidt, 1888, pl. 1, fig. 1, with the exception that the cephalon is not attached as it was theoretically placed there by Schmidt.

Mesonacis torelli (Moberg) 264

FIG. 5. Drawn from a plaster cast of the cephalon figured by Moberg [1899, pl. 15, fig. 1*a*]. Natural size. The cast is in the U. S. National Museum, Catalogue No. 24631*a*.

5*a*. Side view of the specimen represented by fig. 5, showing base of cephalic spine.

Figure 5*a* is copied from Moberg, 1899, pl. 15, fig. 1*b*.

6. Central portions of a cephalon. Natural size. U. S. National Museum, Catalogue No. 56793*a*.

7. Genal angle and spine. × 1.5.

Figure 7 is copied from Moberg, 1899, pl. 15, fig. 4.

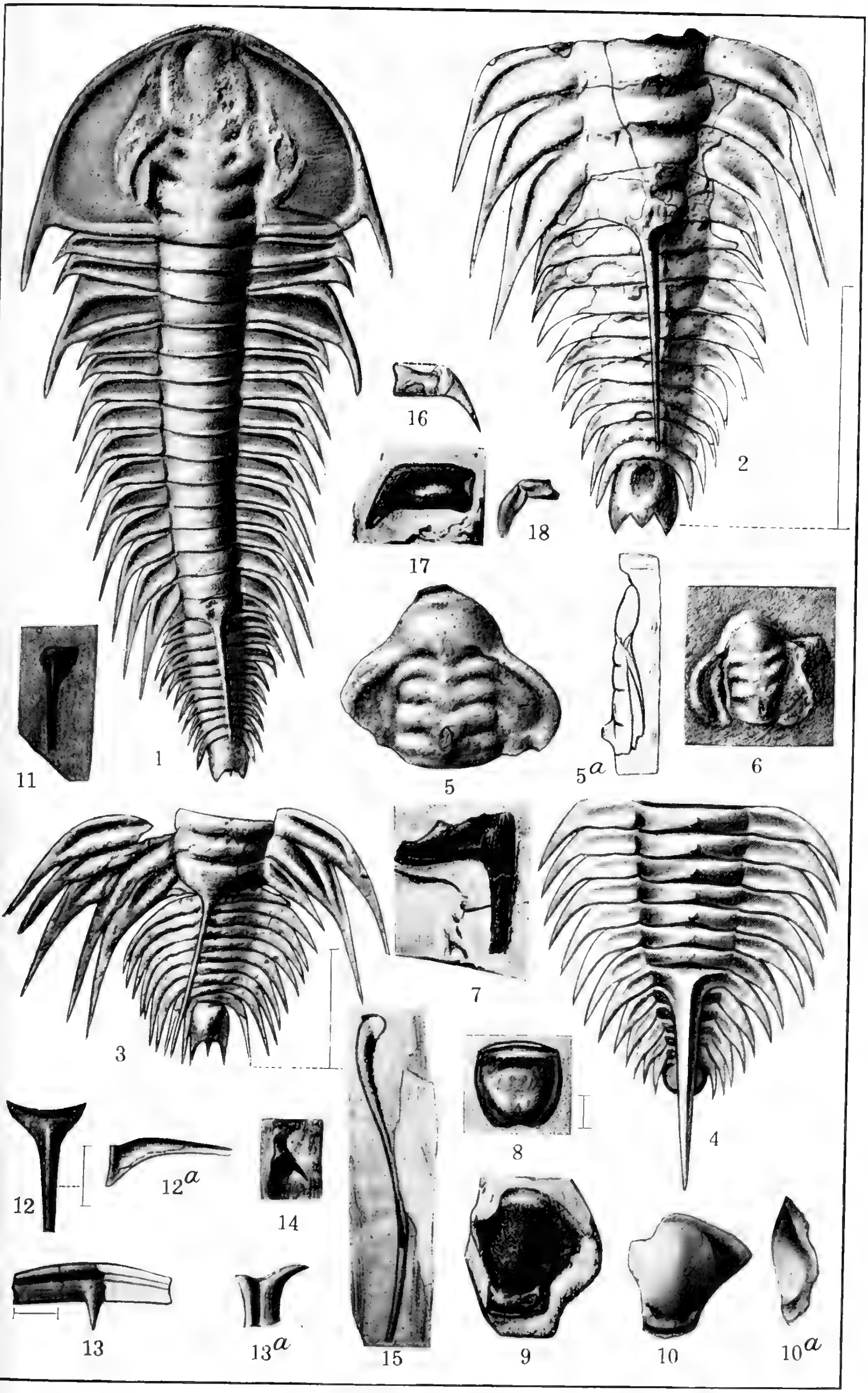
8. Drawn from a plaster cast of the pygidium figured by Moberg [1899, pl. 15, fig. 14]. × 2. Cast in U. S. National Museum, Catalogue No. 24631*b*.

9. Hypostoma. × 1.5.

Figure 9 is copied from Moberg [1899, pl. 15, fig. 6]. The specimen is redrawn in figs. 10 and 10*a* of this plate.

10 and 10*a*. Top and side view of a plaster cast of the hypostoma figured by Moberg and copied in fig. 9 of this plate. × 1.5. Cast in U. S. National Museum, Catalogue No. 24631*c*.

11. Thoracic spine. × 1.5. [After Moberg, 1899, pl. 15, fig. 15.] Cast in U. S. National Museum, Catalogue No. 24631*d*.



LOWER CAMBRIAN TRILOBITES

Mesonacis torelli (Moberg) (continued):

12 and 12*a*. Thoracic spine, top and side view. × 2. U. S. National Museum, Catalogue No. 56793*b*.

13 and 13*a*. Fragment of the axial lobe of a thoracic segment with a short, strong, median spine. × 2. U. S. National Museum, Catalogue No. 56793*c*.

14. Fragment of the axial lobe of a thoracic segment viewed in the same position as that of fig. 13*a*. [After Moberg, 1899, pl. 15, fig. 12.] Cast in U. S. National Museum, Catalogue No. 24631*e*.

15. A long spine. × 1.5. [After Moberg, 1899, pl. 15, fig. 16.] Cast in U. S. National Museum, Catalogue No. 24631*f*.

16 and 17. Pleuræ from the anterior portion of the thorax. × 1.5. Figure 16 represents the under side partly concealed by the matrix and fig. 17 the upper or outer side. [After Moberg, 1899, pl. 15, figs. 8 and 7, respectively.]

18. Fragment of a posterior thoracic segment. × 1.5. [After Moberg, 1899, pl. 15, fig. 10.]

All of the specimens represented by figs. 5-18 are from locality (321*v*), near Bjorkelunda, Sweden.

The originals from which Moberg's figures were drawn are in the collections of the Geological Institution of the University of Lund, Sweden.

DESCRIPTION OF PLATE 27

PAGE

Callavia bröggeri (Walcott) (See pl. 44) 279

FIG. 1. Restoration of the dorsal shield of this species, based on a large number of partially preserved fragments in the limestone and numerous nearly entire specimens compressed in the shale. The specimens in the limestone show the convexity and those in the shale the general proportion and number of segments. Two-thirds natural size. Locality (41), Conception Bay, Newfoundland. U. S. National Museum, Catalogue No. 18331.

2. Hypostoma in shale attached to the doublure. Natural size. Locality (41), Conception Bay, Newfoundland. U. S. National Museum, Catalogue No. 18331*a*.

3. Portion of a cheek in limestone with the genal and intergenal spines. Natural size. Locality (42), Conception Bay, Newfoundland. U. S. National Museum, Catalogue No. 18331*b*.

4. A small, imperfectly preserved convex cephalon in shale. Natural size. Same locality as fig. 2. U. S. National Museum, Catalogue No. 18331*c*.

5. Fragments of the posterior four thoracic segments and pygidium compressed in the shale. Natural size. Same locality as fig. 2. U. S. National Museum, Catalogue No. 18331*d*.

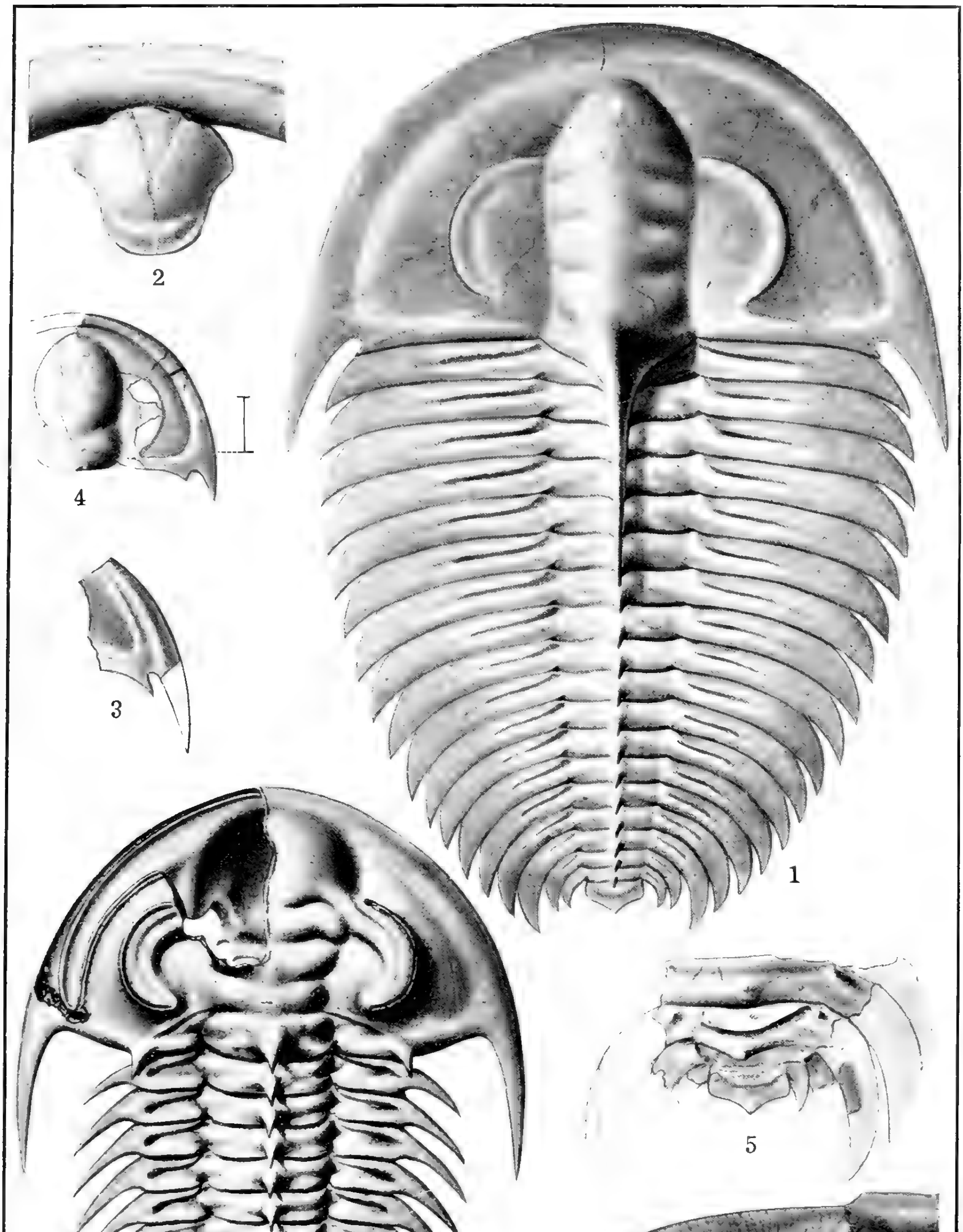
6. Falcate extension of the pleural lobe of a thoracic segment. $\times 2$. Same locality as fig. 2. U. S. National Museum, Catalogue No. 18331*e*.

Figures 1 to 6 are reproduced from drawings illustrating this species in the Tenth Ann. Report U. S. Geol. Survey. [Walcott, 1891] as follows: fig. 1 = pl. 91, fig. 1; fig. 2 = pl. 92, fig. 1*e*; fig. 3 = pl. 92, fig. 1*h*; fig. 4 = pl. 92, fig. 1*g*; fig. 5 = pl. 92, fig. 1*c*; fig. 6 = pl. 92, fig. 1*d*.

Holmia kjerulfi (Linnarsson) (See pl. 44) 288

FIG. 7. An entire adult dorsal shield with the glabella cut away so as to show the outline of the hypostoma. $\times 2$.

Figure 7 is copied from Holm, 1887, pl. 14, fig. 2.



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LOWER CAMBRIAN TRILOBITES

DESCRIPTION OF PLATE 28

PAGE

Callavia crosbyi, new species.. 284

FIG. 1. Portion of a large cephalon showing some of the characteristic features of the species. Natural size. U. S. National Museum, Catalogue No. 56798*a*.

2. Fragments of a cephalon showing an accidental contraction of the posterior portion of the glabella. Natural size. U. S. National Museum, Catalogue No. 56798*b*.

3. A cephalon preserving the convexity, entire eye lobes and general characters more perfectly than usual, owing to the compression in the matrix of nearly all other specimens. Natural size. U. S. National Museum, Catalogue No. 56798*c*.

4. A specimen preserving the cephalon and a number of the thoracic segments. Natural size. U. S. National Museum, Catalogue No. 56798*d*.

5. Portion of a large thoracic segment. Natural size. U. S. National Museum, Catalogue No. 56798*e*.

6. A partially restored hypostoma. Natural size. U. S. National Museum, Catalogue No. 56798*f*.

7. Enlargement of highly ornamented surface of the outer border and portion of the side of the cephalon. Natural size. U. S. National Museum, Catalogue No. 56798*a*.

8. A specimen preserving the cephalon, sixteen segments of the thoracic axis, and a distorted pygidium. $\times 2$. The thoracic axis and pygidium have been compressed from the sides and thus narrowed nearly one-third. U. S. National Museum, Catalogue No. 56798*g*.

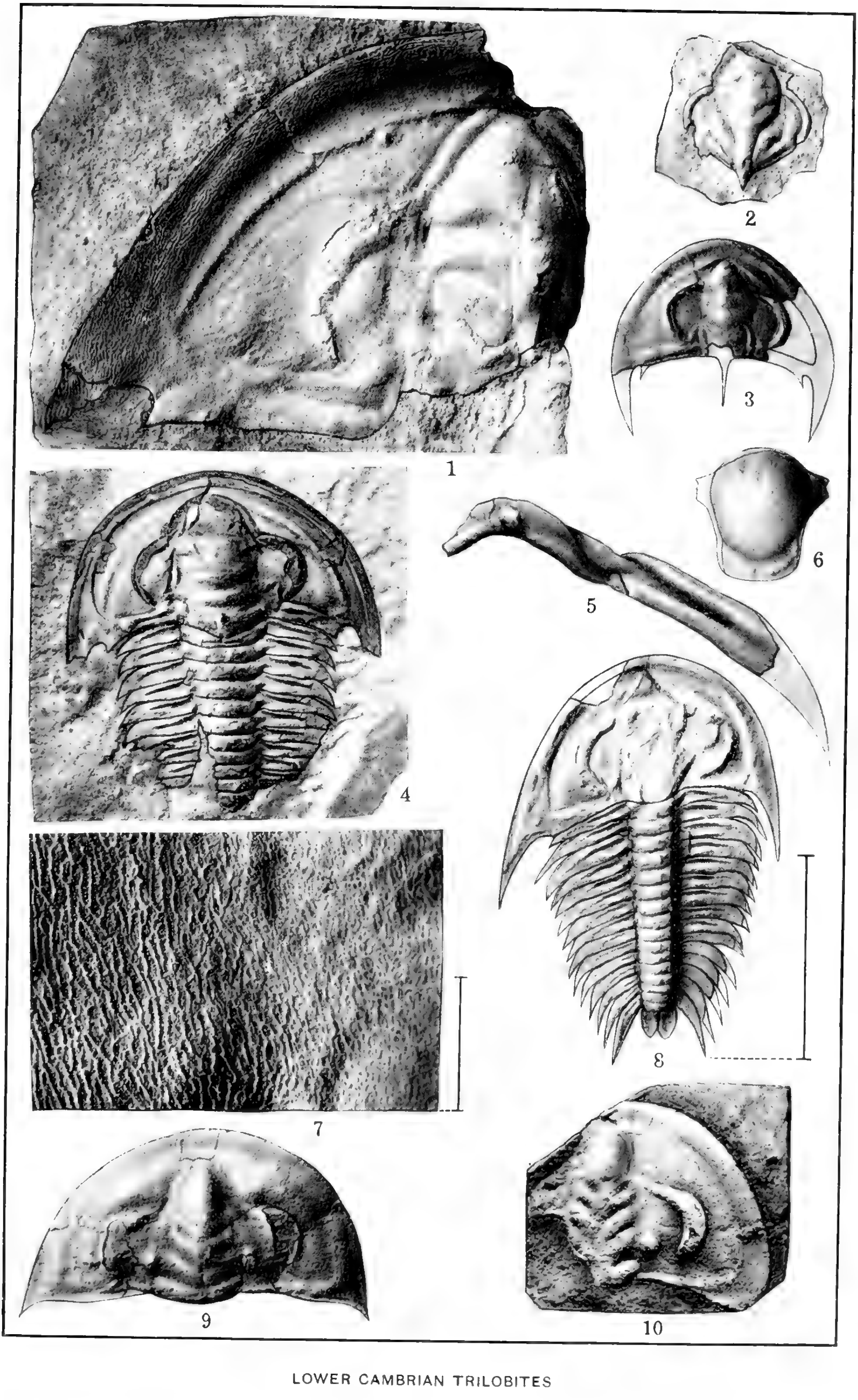
The specimens represented by figs. 1-8 are all from locality (9*n*), near North Weymouth, Massachusetts.

Callavia burri, new species.. 280

FIG. 9. A very well preserved cephalon in the collection of the Museum of Comparative Zoology, Cambridge, Massachusetts. Natural size. Cast in U. S. National Museum, Catalogue No. 56795*a*.

10. A portion of a cephalon showing the palpebral lobe, tubercle between the palpebral lobe and glabella and the marginal rim. Natural size. U. S. National Museum, Catalogue No. 56795*b*.

The specimens represented by figs. 9-10 are from locality (9*n*), near North Weymouth, Massachusetts.



LOWER CAMBRIAN TRILOBITES

DESCRIPTION OF PLATE 29

FIGS. 1 and 2. Two flattened specimens of the cephalon showing strong marginal rim, genal spines, and occipital spine. Natural size. U. S. National Museum, Catalogue Nos. 56801*a* and 56801*b*, respectively.

3. A nearly entire specimen of the dorsal shield with seventeen thoracic segments, the cephalon, and a portion of the pygidium. Natural size. U. S. National Museum, Catalogue No. 56801*c*.

4. A portion of the thorax preserving seventeen segments and showing the form of the termination of the segments. $\times$ 2. U. S. National Museum, Catalogue No. 56801*d*.

5. A portion of the cephalon and thorax. Note the very long genal spine. Natural size. U. S. National Museum, Catalogue No. 56801*e*.

6. A nearly entire cephalon. $\times$ 2. U. S. National Museum, Catalogue No. 56801*f*.

7. Enlargement of a portion of the outer surface of the cheek of the cephalon showing scattered tubercles. $\times$ 9. U. S. National Museum, Catalogue No. 56801*g*.

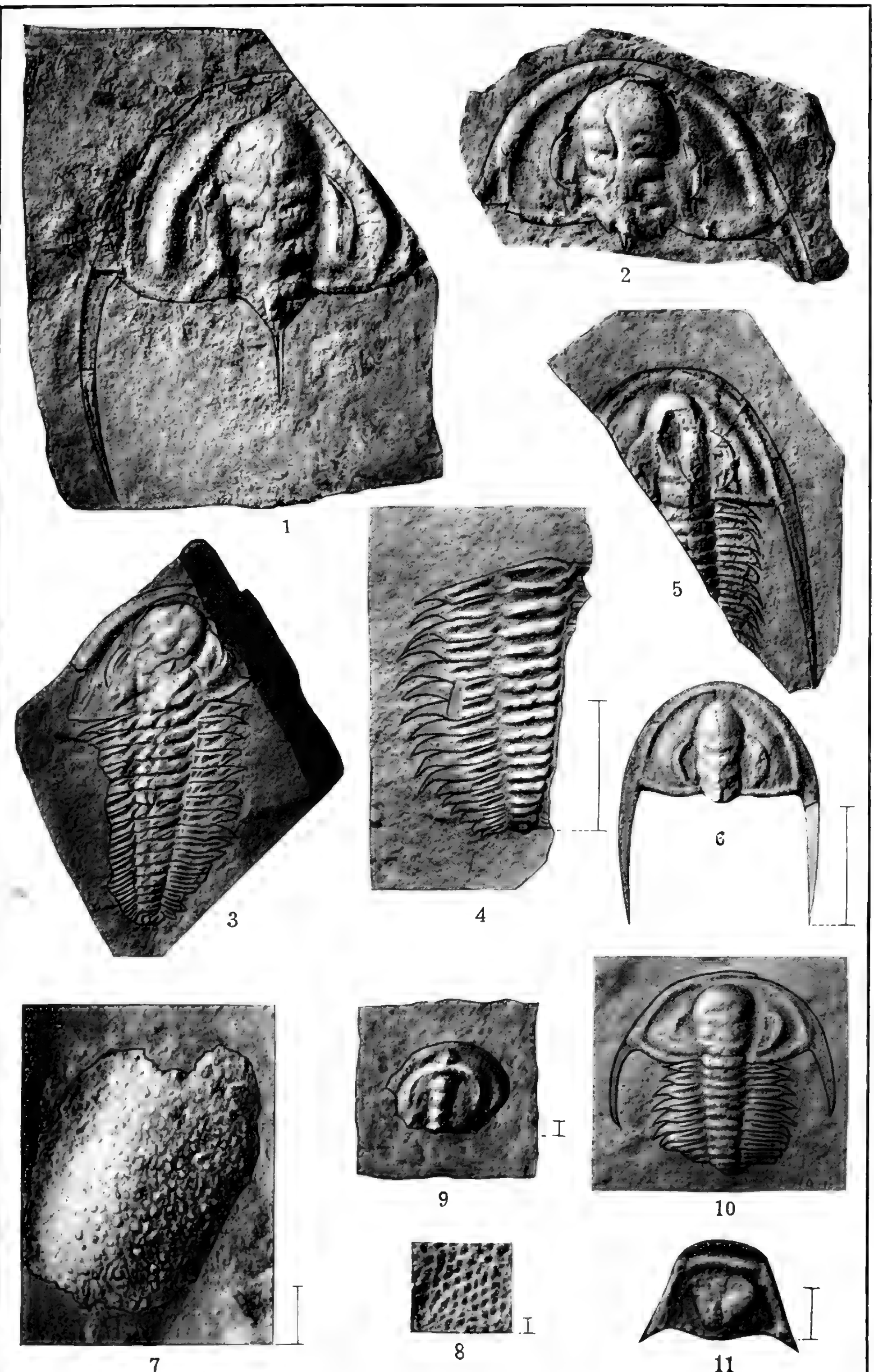
8. Enlargement of a portion of the surface of the cheek on which the reticulated net work formed by narrow ridges is very clearly shown. $\times$ 12. U. S. National Museum, Catalogue No. 56801*h*.

9. Fragment of a minute cephalon showing a young stage of growth. $\times$ 12. Compare with young of *Wanneria halli* (pl. 31, figs. 5 and 8), *Elliptocephala asaphoides* (pl. 25, figs. 9 and 10), and *Pædeumias transitans* (pl. 25, fig. 21). U. S. National Museum, Catalogue No. 56801*i*.

10. A small specimen of the cephalon with a portion of the thorax. Natural size. U. S. National Museum, Catalogue No. 56801*j*.

11. The only entire pygidium found in the collection. $\times$ 2. U. S. National Museum, Catalogue No. 56801*k*.

All the specimens represented on this plate are from locality (1*f*), 10 miles south of Silver Peak and three miles northeast of Barrel Spring, Nevada.



LOWER CAMBRIAN TRILOBITES

DESCRIPTION OF PLATE 30

PAGE

Wanneria walcottanus (Wanner) (See pls. 31 and 44) 302

FIG. 1. An entire adult specimen flattened in the shales and with the test largely exfoliated. Natural size. U. S. National Museum, Catalogue No. 56807*a*.

2. A well preserved flattened cephalon. Natural size. U. S. National Museum, Catalogue No. 56807*b*.

3 and 4. Small cephalons showing the increase in the size of the eye in the younger stages of growth. Natural size. In *Wanneria halli* (pl. 31) this feature of the cephalon is more fully illustrated. U. S. National Museum, Catalogue Nos. 56807*c* and 56807*d*, respectively.

5. Hypostoma crushed and displaced from its true position in relation to the doublure of the cephalon. Natural size. U. S. National Museum, Catalogue No. 56807*e*.

6. Cast of the under side of the doublure of the cephalon, with casts of the spines along its posterior margin. Natural size. U. S. National Museum, Catalogue No. 56807*f*.

7. An unusually well preserved hypostoma with six spines on each postero-lateral margin. Natural size. U. S. National Museum, Catalogue No. 56807*g*.

The specimens represented by figs. 5, 6, and 7 were figured by Wanner [1901, pl. 32, figs. 2, 1, and 3, respectively].

8. Distorted pygidium of an adult individual from near York, Pennsylvania. $\times$ 3. U. S. National Museum, Catalogue No. 56807*h*.

9. Cast of the under side of the genal spine and the doublure. $\times$ 2. Note the cast of the small spines on the margin of the doublure. U. S. National Museum, Catalogue No. 56807*i*.

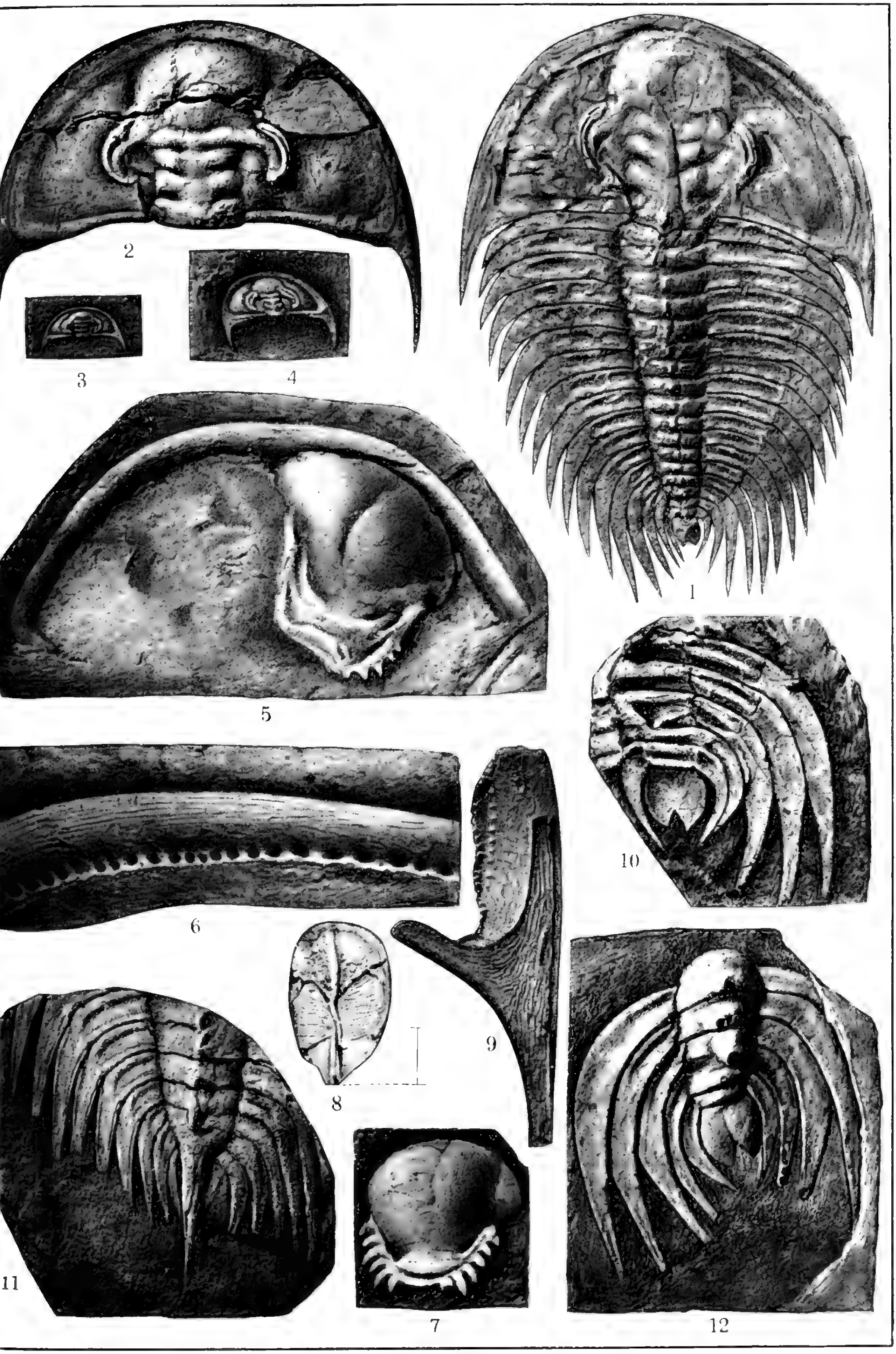
10. Matrix of a pygidium and five posterior thoracic segments. $\times$ 2. Note the cast of the median spine at the third segment from the pygidium. U. S. National Museum, Catalogue No. 56807*j*.

11. Posterior portion of a large individual preserving a strong spine on the axial lobe of the third thoracic segment from the pygidium, also, a small spine on the fourth segment. Natural size. U. S. National Museum, Catalogue No. 56807*k*.

12. Pygidium and five posterior thoracic segments with base of strong spine on third segment and small spine on fourth segment from the pygidium. $\times$ 2. U. S. National Museum, Catalogue No. 56807*l*.

The specimens represented by figs. 5-7, 9-12, were collected by Prof. A. Wanner. The greatest addition to our information of the species is furnished by figs. 11 and 12.

All of the specimens represented on this plate are from locality (8*q*), 2 miles northwest of the city of York, Pennsylvania.



LOWER CAMBRIAN TRILOBITES

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DESCRIPTION OF PLATE 31

PAGE

Wanneria halli, new species.. 301

FIGS. 1, 2, and 3. Cephalons with genal angles and spines in advance of the posterior margin of the head and with intergenal angles almost right angles. No. 1, × 1.25; No. 2, × 3; No. 3, natural size. U. S. National Museum, Catalogue Nos. 56806*a*, 56806*b*, and 56806*c*, respectively.

4. A small cephalon with short, minute intergenal spine at the intergenal angle. Glabella cylindrical, eye lobe large. × 8. U. S. National Museum, Catalogue No. 56806*d*.

5, 7, and 8. Minute cephalons showing rounded-in genal angles, large eye lobes, and contraction of the glabella at the eye lobes. No. 5, × 24; No. 6, × 6; No. 5, × 16. Compare with the younger stages of growth of *Elliptocephala asaphoides* (pl. 25) and *Pædeumias transitans* (pls. 25 and 32). U. S. National Museum, Catalogue Nos. 56806*e*, 56806*g*, and 56806*h*, respectively.

6. Fragment of a minute cephalon with strong eye lobe, minute genal and intergenal spines. × 16. U. S. National Museum, Catalogue No. 56806*f*.

9. Hypostoma associated with this species in Alabama. × 12. U. S. National Museum, Catalogue No. 56806*i*.

10. Under side or doublure of the extension of the pleuræ beyond the body line of a thoracic segment. × 2. U. S. National Museum, Catalogue No. 56806*j*.

11. Upper side of the pleural lobe of a thoracic segment. × 3. U. S. National Museum, Catalogue No. 56806*k*.

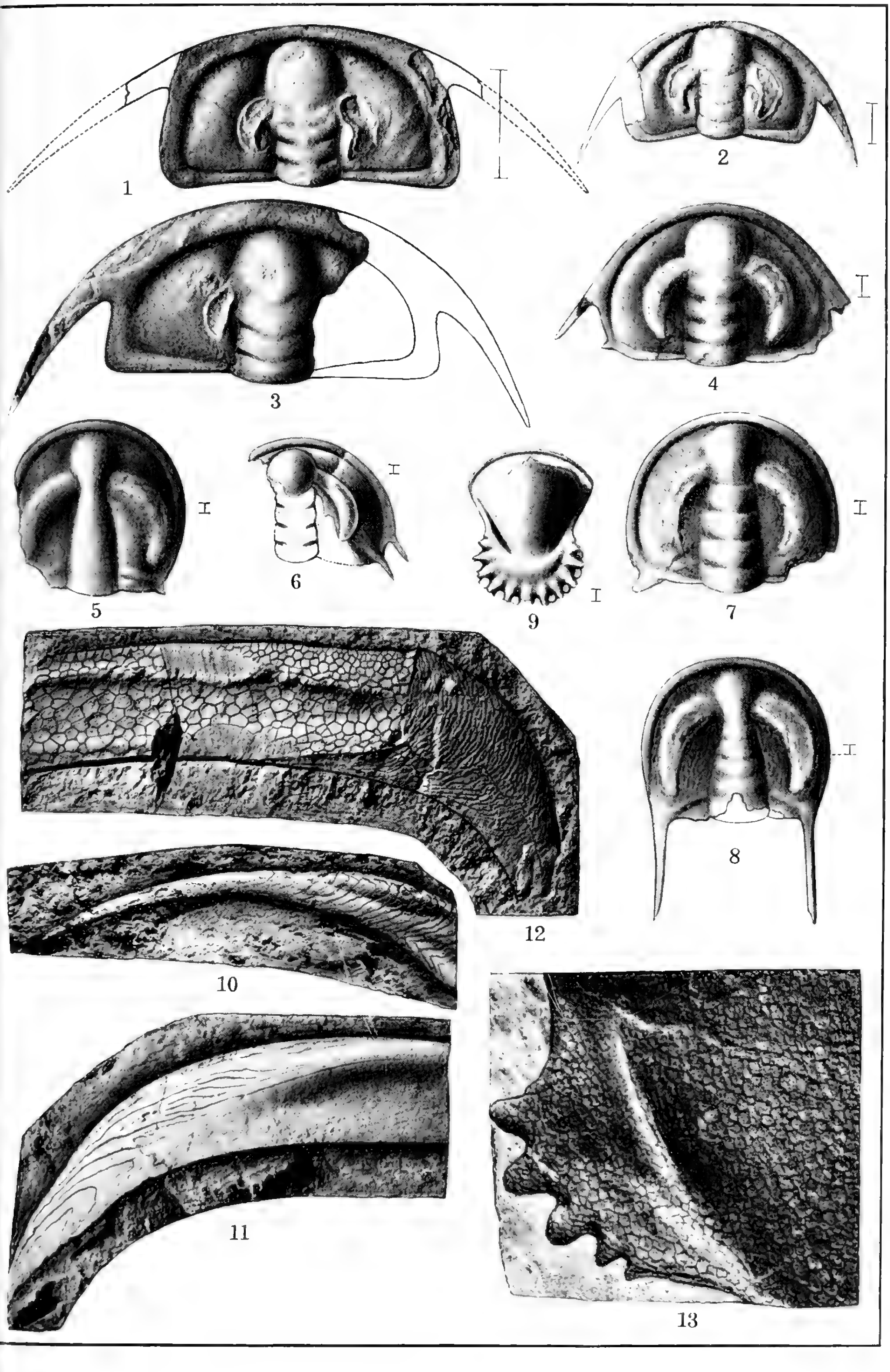
All the specimens represented by figs. 1-11 are from locality (56*c*) north of Helena, Shelby County, Alabama.

Wanneria walcottanus (Wanner) (See pls. 30 and 44)................. 302

FIG. 12. Enlargement of the pleural lobe of a thoracic segment. × 2. This specimen was illustrated by Wanner [1901, pl. 31, fig. 2]. U. S. National Museum, Catalogue No. 56807*m*.

13. A portion of the postero-lateral part of an hypostoma (× 6), showing surface markings and five of the short obtuse marginal spines. U. S. National Museum, Catalogue No. 56807*n*.

The specimens represented by figs. 12 and 13 are from locality (8*q*), 2 miles northwest of York, Pennsylvania.



LOWER CAMBRIAN TRILOBITES

DESCRIPTION OF PLATE 32

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Pædeumias transitans, new genus and new species (See pls. 24, 25, 33, 34, 41, and 44) 305

FIG. 1. A cephalon 1 mm. in length, exclusive of the intergenal spines. $\times$ 16. U. S. National Museum, Catalogue No. 56810*a*.

2. A dorsal shield with five thoracic segments and pygidium, 1.5 mm. in length, exclusive of the long intergenal spines. $\times$ 12. U. S. National Museum, Catalogue No. 56810*b*.

3. A dorsal shield with seven or eight thoracic segments and pygidium, 1.75 mm. in length, exclusive of the intergenal spines. $\times$ 10. U. S. National Museum, Catalogue No. 56810*c*.

4. A dorsal shield 3.5 mm. in length with ten segments, pygidium, and large third thoracic segment. $\times$ 6. U. S. National Museum, Catalogue No. 56810*d*.

5. A dorsal shield of about the same size as that represented by fig. 4, that has a very narrow thorax. $\times$ 6. U. S. National Museum, Catalogue No. 56810*e*.

6. A dorsal shield 4.25 mm. in length, exclusive of spines, with 12 thoracic segments and large third segment with pleura very much prolonged. Pygidium broken away. $\times$ 4. U. S. National Museum, Catalogue No. 56810*f*.

7. A dorsal shield 4.25 mm. in length, but shortened by compression, with 13 thoracic segments and a small pygidium. $\times$ 4. U. S. National Museum, Catalogue No. 56810*g*.

8. Two small and very distinct cephalons. $\times$ 4. U. S. National Museum, Catalogue No. 56810*h*.

9. This figure is to illustrate the natural curvature of the spine on the fifteenth thoracic segment. Natural size. U. S. National Museum, Catalogue No. 56810*i*.

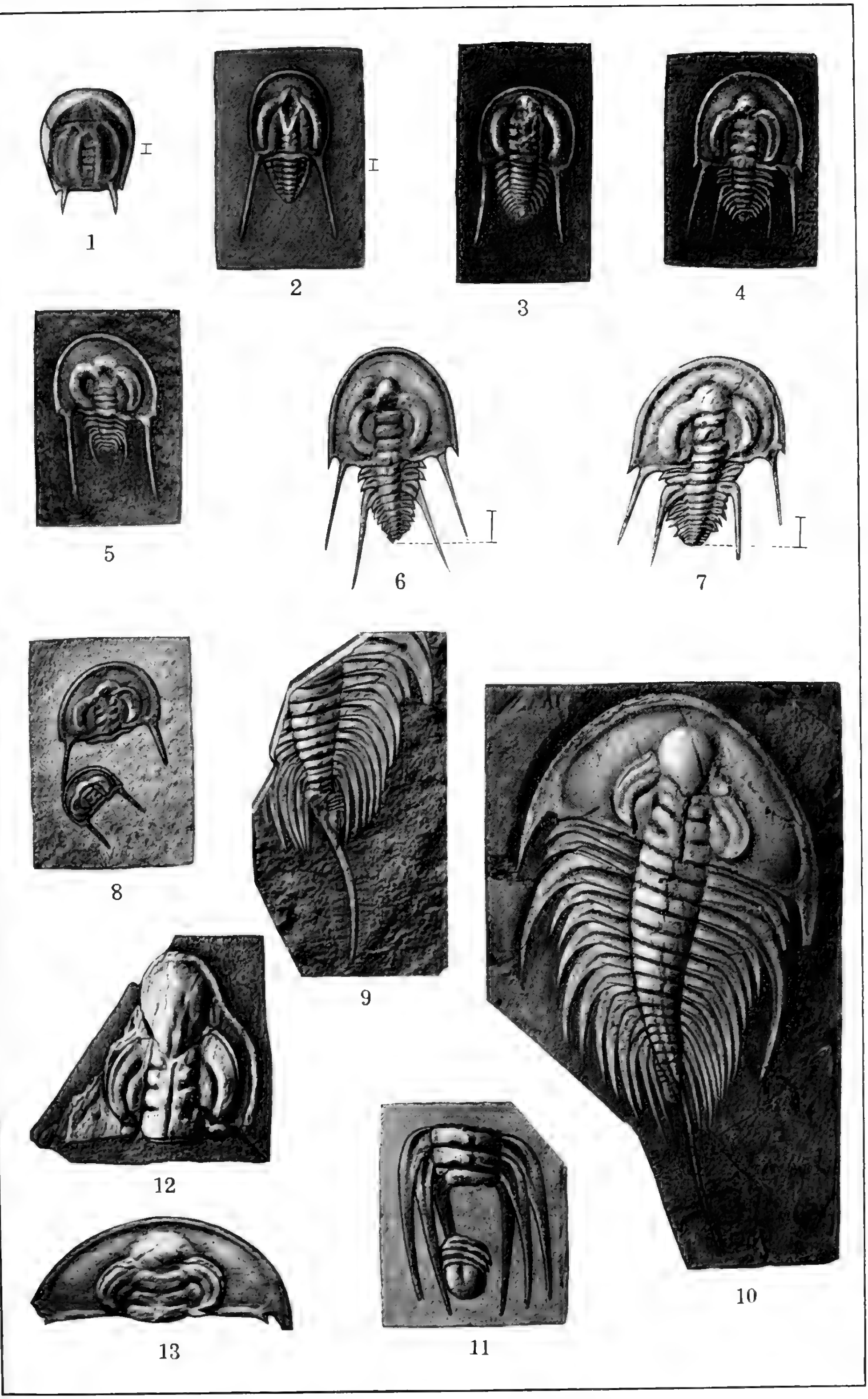
10. An entire specimen of the dorsal shield from York, Pennsylvania, showing four very narrow segments and a plate-like pygidium beneath the large spine on the fifteenth segment. Natural size. U. S. National Museum, Catalogue No. 56810*j*.

11. Displaced pygidium and two posterior rudimentary segments of a dorsal shield in which the spine bearing segment is broken away. $\times$ 3. U. S. National Museum, Catalogue No. 56810*k*.

12. A cephalon compressed laterally so as to crowd the outer rim in about the eyes and anterior portion of the glabella. Natural size. U. S. National Museum, Catalogue No. 56810*l*.

13. A cephalon compressed longitudinally and broadened. Natural size. U. S. National Museum, Catalogue No. 56810*m*.

All of the specimens represented on this plate are from locality (8*q*), northwest of the City of York, Pennsylvania. Most of them were collected by Prof. Atreus Wanner.



LOWER CAMBRIAN TRILOBITES

DESCRIPTION OF PLATE 33

PAGE

Pædeumias transitans, new genus and new species (See pls. 24, 25, 32, 34, 41, and 44) 305

FIG. 1. A large, broad specimen with three rudimentary thoracic segments posterior to the fifteenth spine bearing segment. Natural size. The posterior three segments and pygidium are illustrated on plate 24. From locality (25), Parkers quarry, Georgia, Vermont. U. S. National Museum, Catalogue No. 56808*a*.

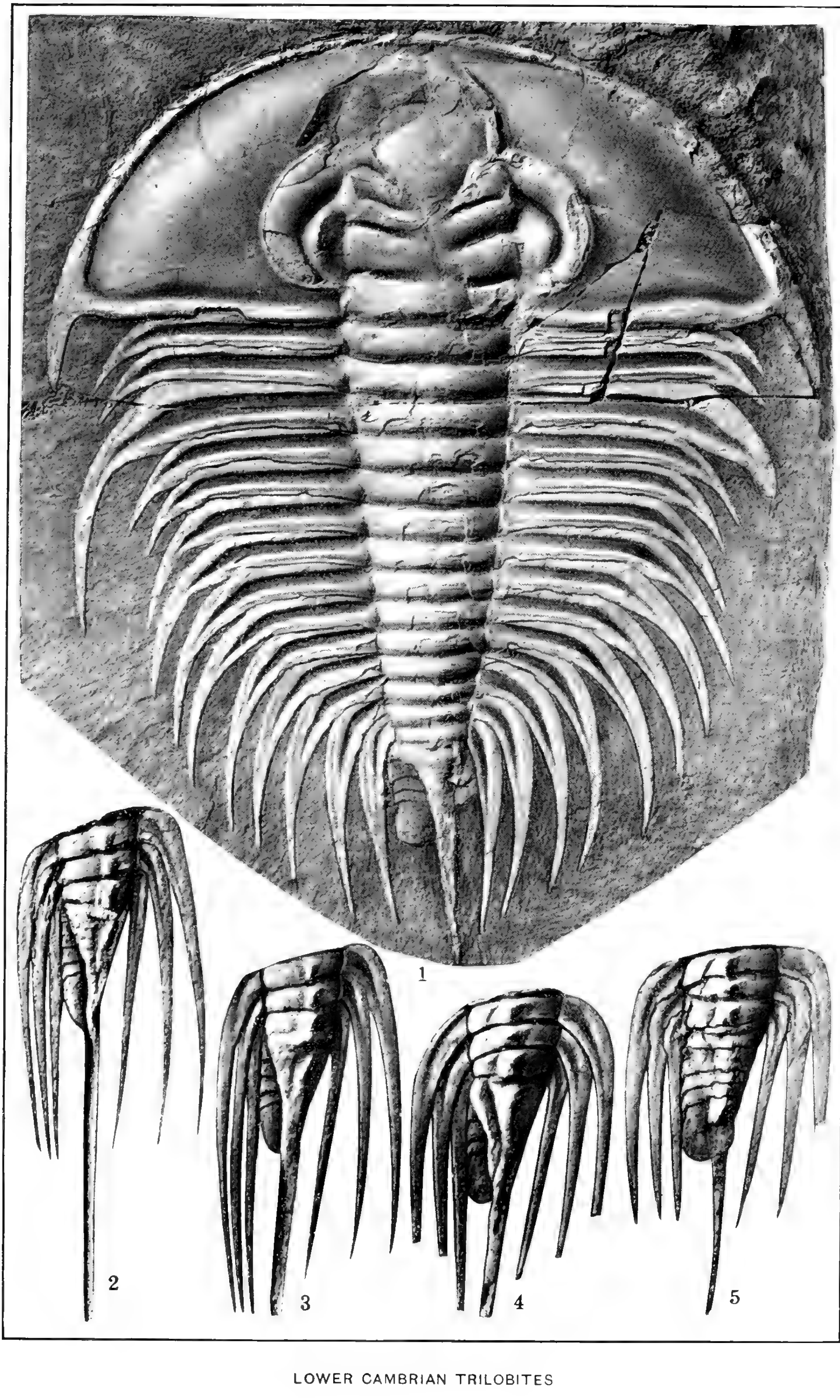
2. Posterior portion of a dorsal shield from which the upper portion of the great spine of the fifteenth thoracic segment has been removed. It shows the pygidium, four rudimentary segments, and the impression of the under side of the great spine. $\times$ 3. U. S. National Museum, Catalogue No. 56810*n*.

3. Photograph from cast in natural matrix of posterior segments, telson, and traces of rudimentary segments and pygidium represented by fig. 2. $\times$ 3. U. S. National Museum, Catalogue No. 56810*n*.

4. View of another specimen similar to that represented by fig. 3. $\times$ 3. This is the exterior of the great spine that is removed in fig. 5. U. S. National Museum, Catalogue No. 56810*o*.

5. This is the posterior portion of the dorsal shield that is the reverse of the matrix from which the cast represented by fig. 4 was taken. The telson is broken away so as to show the fifteenth segment to which the great spine was attached, and joined to this the first, second, and third rudimentary segments and the plate pygidium. $\times$ 3. U. S. National Museum, Catalogue No. 56810*p*.

The specimens represented by figs. 2-5 were collected by Prof. Atreus Wanner from locality (8*q*), 2 miles northwest of York, Pennsylvania.



LOWER CAMBRIAN TRILOBITES

DESCRIPTION OF PLATE 34

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Pædeumias transitans, new genus and new species (See pls. 24, 25, 32, 33, 41, and 44) 305

FIG. 1. Elongate form of dorsal shield from locality (25), at Parkers quarry, Georgia, Vermont. × 2. U. S. National Museum, Catalogue No. 56808*b*.

2. Elongate form of dorsal shield from York. × 2. U. S. National Museum, Catalogue No. 56810*q*.

3. Broad form of dorsal shield from York. × 1.5. U. S. National Museum, Catalogue No. 56810*r*.

4. A dorsal shield 12 mm. in length with 13 thoracic segments and long terminal telson from York. × 3. U. S. National Museum, Catalogue No. 56810*s*.

5. Hypostoma attached to doublure by a narrow median support. From York. × 2. U. S. National Museum, Catalogue No. 56810*t*.

6. Cephalon with the doublure and hypostoma separated and turned back on the line of the intergenal spines. From York. × 2. U. S. National Museum, Catalogue No. 56810*u*.

7. Hypostoma attached to doublure by a narrow median support. From York. × 3. U. S. National Museum, Catalogue No. 56810*v*.

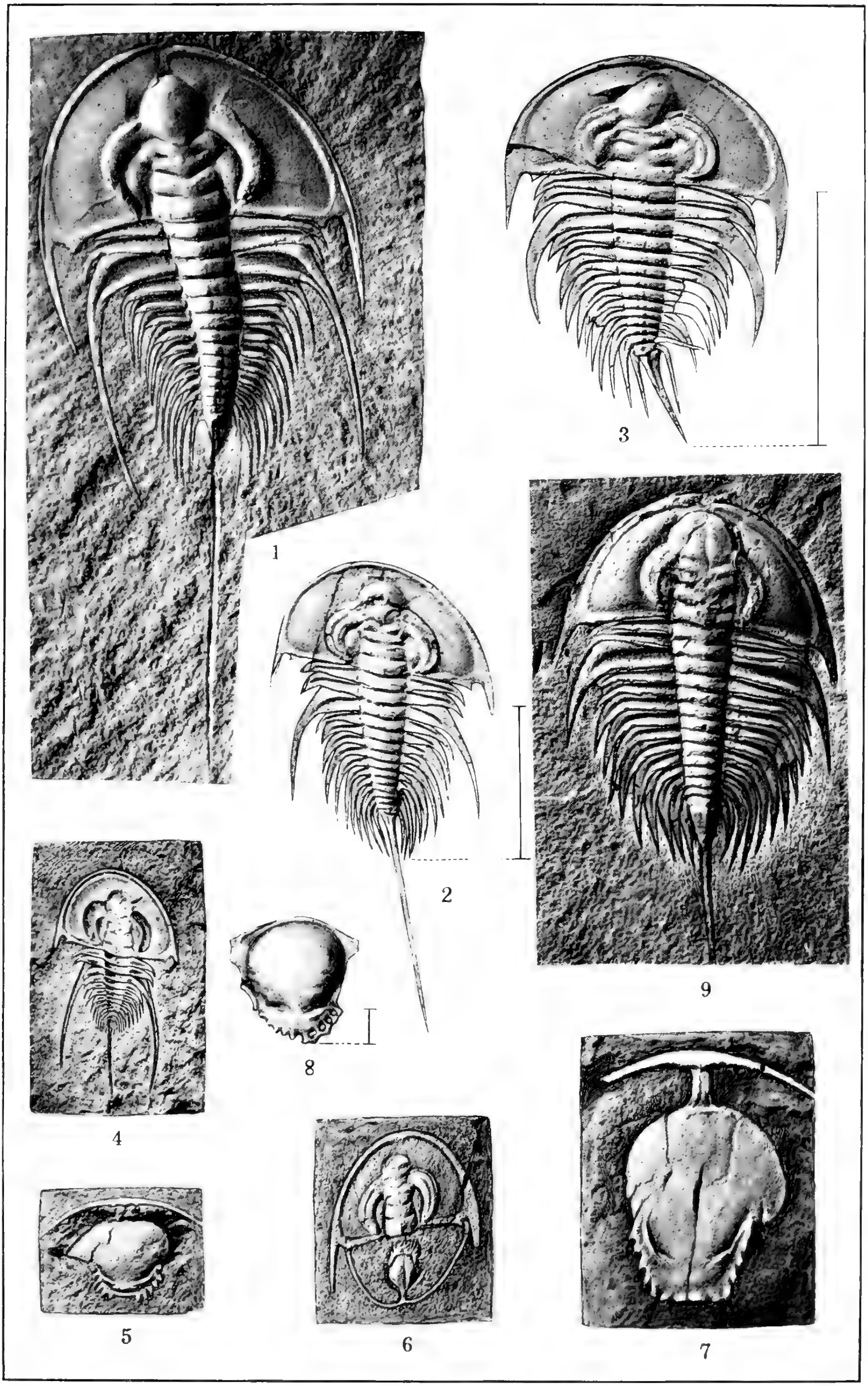
The specimens represented by figs. 2-7 are from locality (8*q*) 2 miles northwest of York, Pennsylvania.

8. Hypostoma from locality (17*a*) near Montevallo, Alabama, showing perforated posterior margin. × 3. U. S. National Museum, Catalogue No. 56811*a*.

Olenellus thompsoni (Hall) (See pls. 35 and 44) 336

FIG. 9. A flattened dorsal shield from locality (25), Parkers quarry, Georgia, Vermont. Natural size. U. S. National Museum, Catalogue No. 15418*a*.

Figure 9 is redrawn from the specimen figured by Walcott, 1886, pl. 17, fig. 2.



LOWER CAMBRIAN TRILOBITES

DESCRIPTION OF PLATE 35

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Olenellus thompsoni (Hall) (See pls. 34 and 44) 336

FIG. 1. Dorsal shield from the type locality (25), at Parkers quarry. Georgia, Vermont. Reduced to two-thirds of natural size. This figure was published [Walcott, 1886, pl. 23, fig. 1] with a space between the glabella and marginal border. The glabella is crushed down even with the surface of the cheeks and the draftsman left out the line indicating the margin of the anterior glabella lobe. The same is true of fig. 1, pl. 22. Figures 2 and 9, pl. 17, represented the correct position of the glabella. U. S. National Museum, Catalogue No. 15418*b*.

2. A large crushed telson from locality (8*q*), 2 miles northwest of the City of York, Pennsylvania. × 1.5. U. S. National Museum, Catalogue No. 56835*a*.

3. Hypostoma that occurs on the inside of a cephalon. Only the base of some of the postero-marginal spines can be seen and the median support, if ever present, is now broken off. Locality (25), Parkers quarry, Georgia, Vermont. × 2. U. S. National Museum, Catalogue No. 15418*c*.

4. Top view of a convex cephalon from the calcareous sandstone at locality (25*a*), near Swanton. Vermont. A restoration based on the specimen represented by this figure was given by Walcott, 1886, pl. 17, fig. 9. Natural size. U. S. National Museum, Catalogue No. 15419*a*.

5 and 6. Two small cephalons from the Rome sandstone, locality (46), west of Cleveland, Tennessee, in which the natural convexity of the cephalon is preserved. This is outlined in 5*a*. U. S. National Museum, Catalogue Nos. 26983*a* and 26983*b*, respectively.

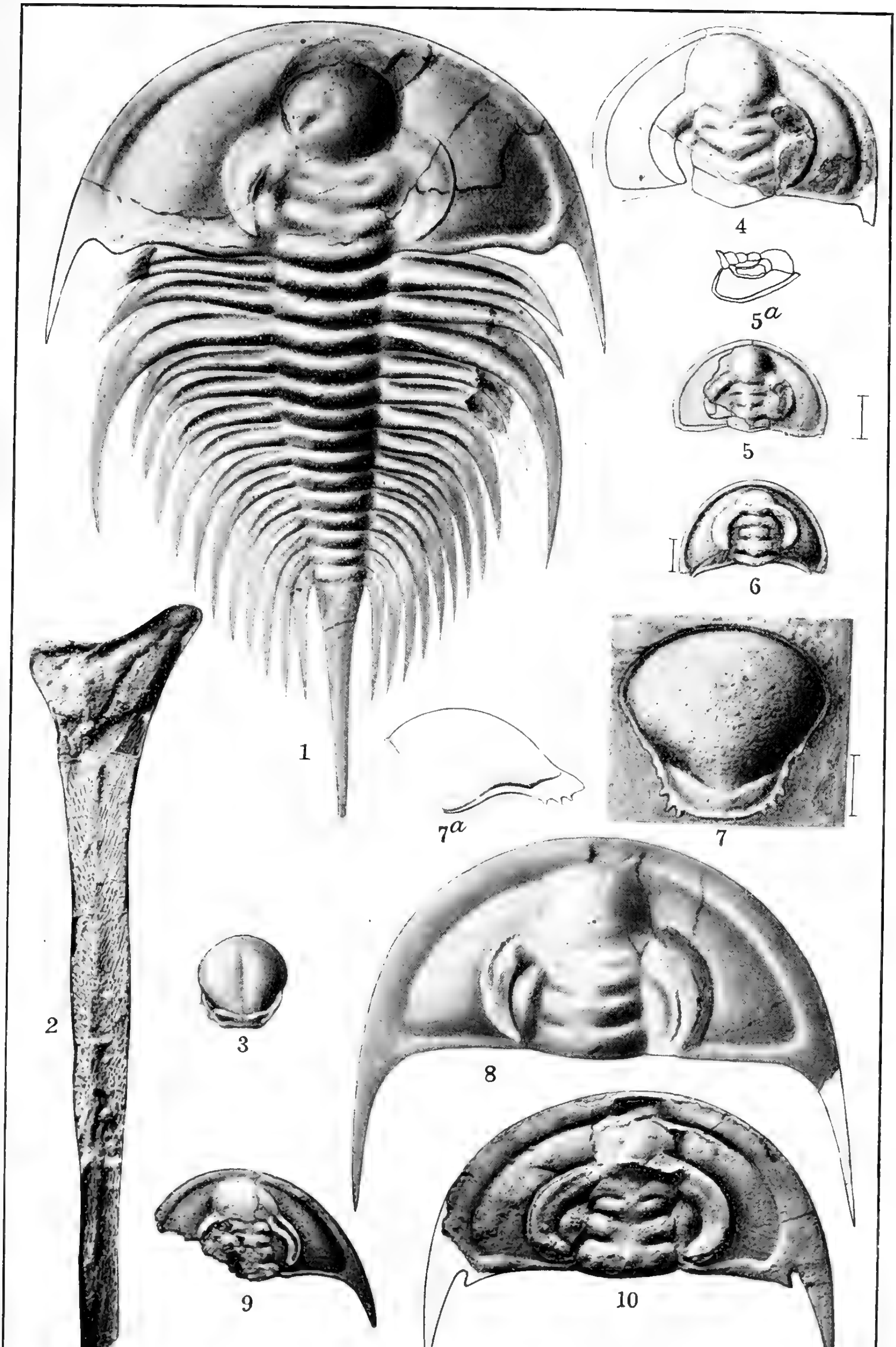
7 and 7*a*. Top and side view (× 3) of a very convex hypostoma from the same locality (46) as the specimens represented by figs. 5 and 6. U. S. National Museum, Catalogue No. 26983*c*.

Olenellus thompsoni crassimarginatus, new variety 340

FIG. 8. A flattened cephalon formerly referred to *Olenellus thompsoni* Hall. Natural size. From locality (25), Parkers quarry, Georgia, Vermont. U. S. National Museum, Catalogue No. 56836*a*.

Figure 8 is copied from Walcott, 1886, pl. 17, fig. 1.

9 and 10. Cephalons from locality (8*q*), 2 miles northwest of the City of York, Pennsylvania. Natural size. U. S. National Museum, Catalogue Nos. 56837*a* and 56837*b*, respectively.



LOWER CAMBRIAN TRILOBITES

DESCRIPTION OF PLATE 36

PAGE

Olenellus gilberti Meek (See pl. 43) 324

Figs. 1, 2, and 3. Cephalons crushed and flattened in a dark argillaceous shale from locality (31*a*), near Pioche, Lincoln County, Nevada. U. S. National Museum, Catalogue Nos. 15411*a*, 15411*b*, and 15411*c*, respectively.

These are the specimens to which Meek assigned the name *Olenellus gilberti*. They were figured by White, 1877, pl. 2, figs. 3*b*, 3*c*, and 3*a*, respectively.

4 and 4*a*. Top and side views of a cephalon preserving its convexity in a granular limestone from the same locality as that given for figs. 1-3. Natural size. U. S. National Museum, Catalogue No. 15411*d*.

This is the specimen upon which Meek based the species *Olenellus howelli*. It was figured by White, 1877, pl. 2, figs. 4*a*-*b*.

5. Small hypostoma × 3, associated with specimens of the cephalon of this species at locality (1*p*), south of Silver Peak, Esmeralda County, Nevada. U. S. National Museum, Catalogue No. 56825*a*.

6 and 7. Cephalons compressed and distorted in fine arenaceous shale. × 2. Drawn from specimens found in locality (1*y*), Clayton Valley, Esmeralda County, Nevada. U. S. National Museum, Catalogue Nos. 56826*a* and 56826*b*, respectively.

8. Cast of the inside of the cheek and genal spine and a small intergenal spine. Natural size. Locality (1*p*), south of Silver Peak, Esmeralda County, Nevada. U. S. National Museum, Catalogue No. 56825*b*.

9. A compressed and slightly distorted dorsal shield. Natural size. Locality (30), 8 miles west of Pioche, Nevada. U. S. National Museum, Catalogue No. 15416*a*.

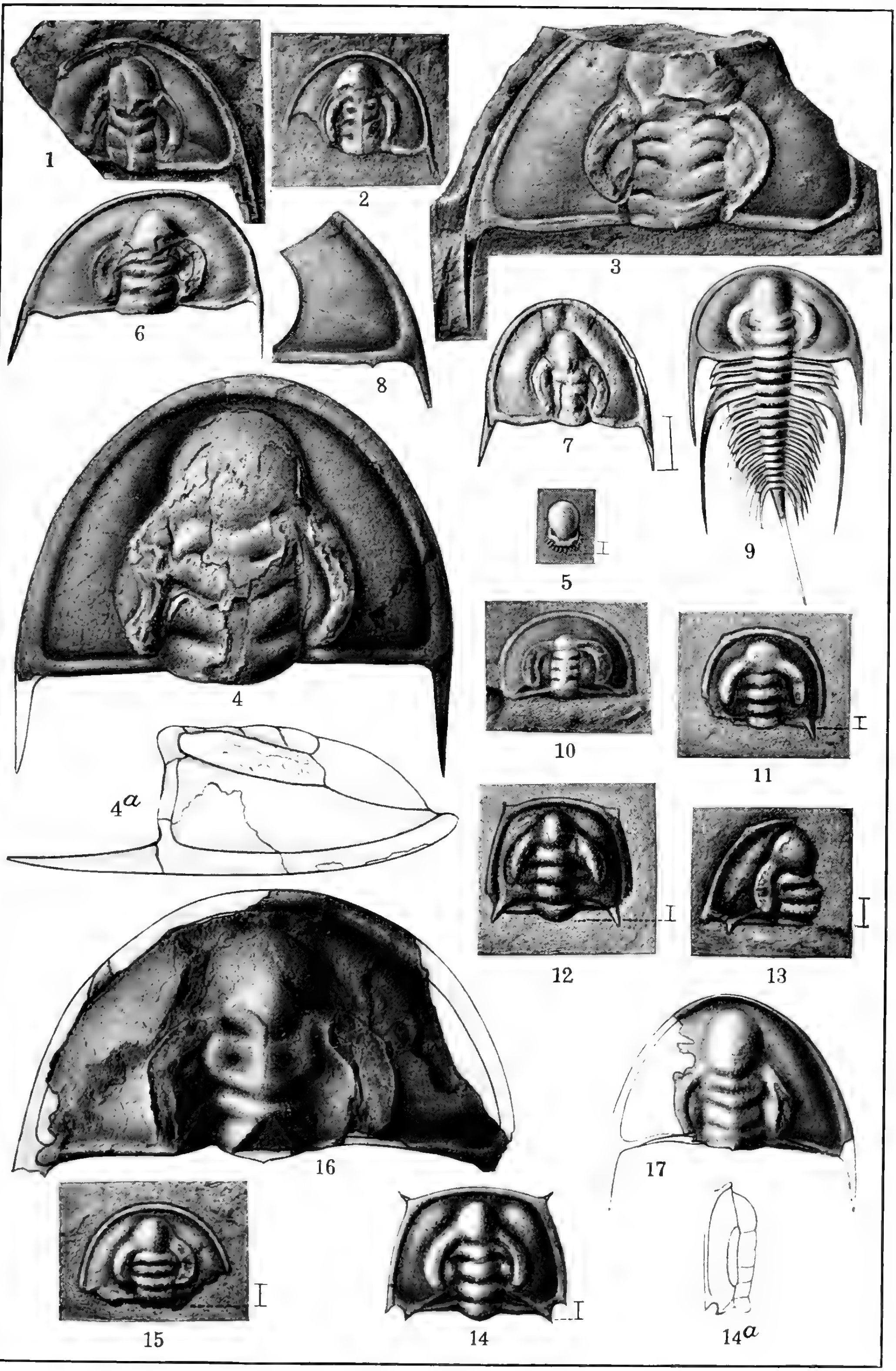
This figure was published by Walcott, 1886, pl. 21, figs. 1, 1*a*; and 1891, pl. 94, figs. 1, 1*a*. In these publications the anterior lobe of the glabella was extended to the front border by error of the draftsman.

10. A small cephalon 2 mm. in length. × 6. Locality (1*m*), south of Silver Peak, Esmeralda County, Nevada. U. S. National Museum, Catalogue No. 56827*a*.

11. A cephalon in which the antero-lateral angles are developed. × 10. U. S. National Museum, Catalogue No. 56828*a*.

12. A slightly larger cephalon than that represented by fig. 1, with large intergenal spines, slightly developed genal angles, and antero-lateral angles and spines. × 10. U. S. National Museum, Catalogue No. 56828*b*.

13. Fragment of a small cephalon × 4, showing intergenal ridge crossing the posterior margin. U. S. National Museum, Catalogue No. 56828*c*.



LOWER CAMBRIAN TRILOBITES

Olenellus gilberti Meek (continued):

14 and 14*a*. Top and side view of a small cephalon with fine antero-lateral and intergenal spines. × 8. U. S. National Museum, Catalogue No. 56828*d*.

15. Small cephalon × 4, in which the antero-lateral angles have disappeared and the palpebral lobes become relatively shorter. U. S. National Museum, Catalogue No. 56828*e*.

16. A large cephalon doubtfully referred to this species. Natural size. U. S. National Museum, Catalogue No. 56829*a*.

17. Fragment of a cephalon that appears to belong to this species. Natural size. U. S. National Museum, Catalogue No. 56829*b*.

The specimens represented by figs. 11-15 are from locality (35*l*), Ptarmigan Pass, Alberta; those by figs. 15-17 from locality (35*f*), above railway tunnel, Mt. Stephen, British Columbia, on the main line of the Canadian Pacific Railway.

DESCRIPTION OF PLATE 37

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Olenellus fremonti, new species (See pl. 41) 320

FIGS. 1 and 1*a*. Top view and side outline of a fragmentary cephalon. Natural size. Locality (14*l*), 15 miles east of Resting Springs, California. U. S. National Museum, Catalogue No. 56818*a*.

2. Cephalon from locality (52), Prospect Mountain, Eureka District, Nevada. Natural size. U. S. National Museum, Catalogue No. 56819*a*.

3 and 3*a*. Top view and side outline of a strongly convex cephalon. Natural size. Locality (176), Deep Spring Valley, Nevada. U. S. National Museum, Catalogue No. 56820*a*.

4. Cast of interior surface of the test of a broad cheek showing the strongly reticulated surface. $\times$ 2. Locality (14*p*), west of Resting Springs, California. U. S. National Museum, Catalogue No. 56821*a*.

5. Enlargement of the outer surface of the broad cheek, the border, and genal spine. $\times$ 2. Same locality as fig. 4. U. S. National Museum, Catalogue No. 56821*b*.

6 and 6*a*. Examples of the enlarged pleuræ of the third thoracic segment. Natural size. From locality (52), the Eureka District, Nevada. U. S. National Museum, Catalogue Nos. 56819*b* and 56819*c*, respectively.

Figure 6 is copied from Walcott, 1886, pl. 19, fig. 2*i;* where it was labeled *Olenellus howelli;* and fig. 6*a* is copied from Walcott, 1884, pl. 9, fig. 15*c,* where the specimen is labeled *Olenellus gilberti.*

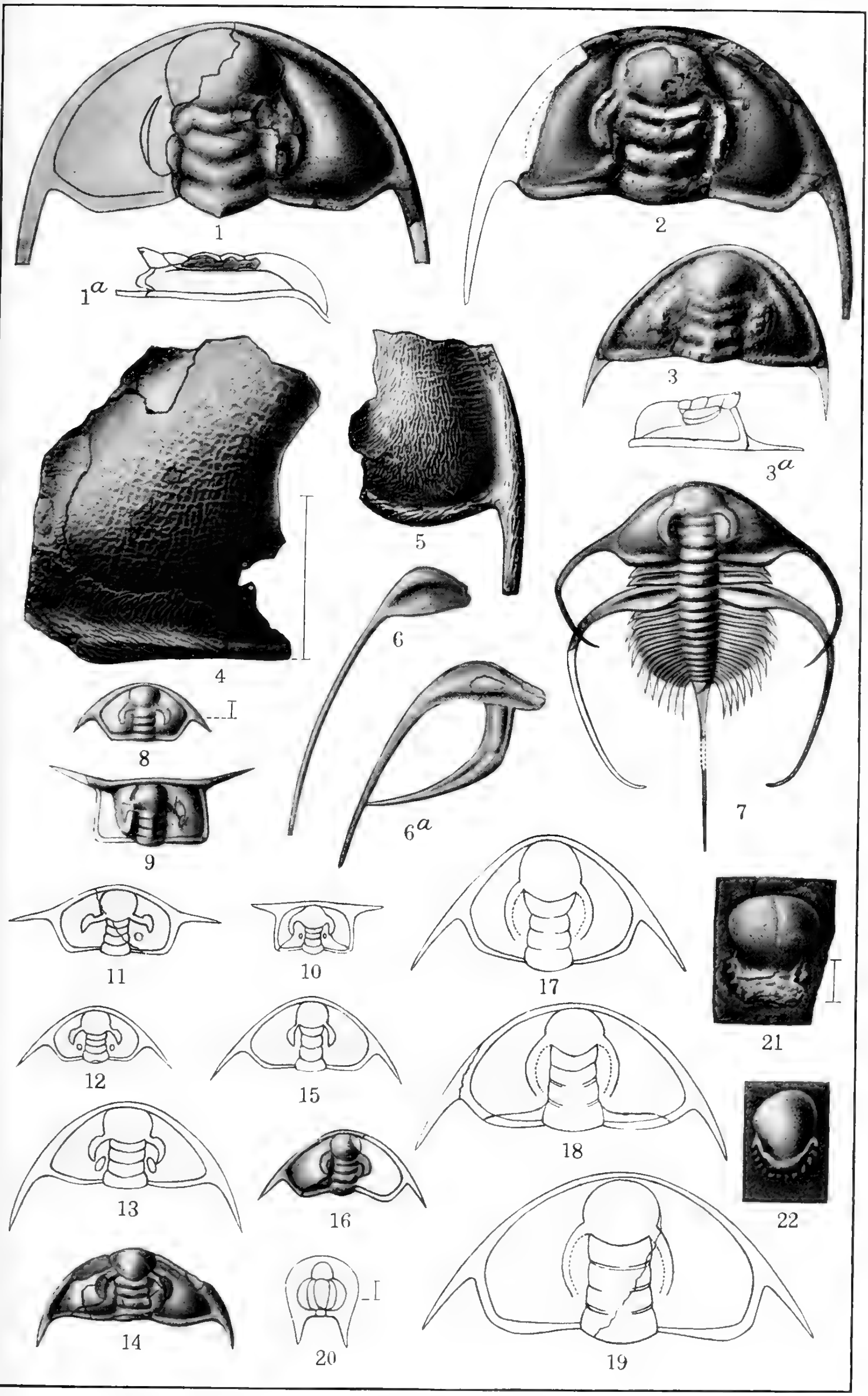
7. Longitudinally compressed form of a nearly entire specimen of the dorsal shield from locality (30), western side of the Highland Range, Lincoln County, Nevada. Natural size. U. S. National Museum, Catalogue No. 56822*a*.

Figure 7 is copied from Walcott, 1886, pl. 21, figs. 2 and 2*a,* a slight change being made in the cephalon, the eyes being much too long in the original figure. The form was assigned [1886 and 1891*a*] to *Olenellus gilberti.*

8. A small cephalon with short eyes and an ocular ridge. Genal angles advanced about one-half the length of the cephalon. $\times$ 6. Locality (52), Prospect Peak, Eureka District, Nevada. U. S. National Museum, Catalogue No. 56819*d*.

Figure 8 is copied from Walcott, 1884, pl. 9, fig. 15*b,* where it is labeled *Olenellus howelli.*

9. Cephalon with the genal spines on a line with the anterior margin and with the intergenal angles. Eyes short and connected with anterior lobe of the glabella by occular ridges. Natural size. The specimen represented is from a limestone at the south end of the Timpahute Range, Nevada (locality



LOWER CAMBRIAN TRILOBITES

Olenellus fremonti, new species (continued):

313*g*). Associated fragments of other cephalons show the genal spines located in the same relative positions as those shown by figs. 10 to 13 from locality (51), Prospect Peak, Nevada. U. S. National Museum, Catalogue No. 56819*e*.

Figure 9 is copied from Walcott, 1886, pl. 20, fig. 1*f*, where it is labeled *Olenellus gilberti.*

This specimen is redrawn (× 6) on pl. 41, fig. 8.

10. Cephalon from locality (52) in the Eureka District, Nevada, that is very much like fig. 9. Natural size. U. S. National Museum, Catalogue No. 56819*f*.

11, 12, and 13. Outlines of specimens of the cephalon with the genal spines and intergenal angles more and more like the normal type of cephalon as shown by figs. 7 and 14. The eyes are short and connected with the glabella by an occular ridge. Natural size. Locality (52), Prospect Mountain, Eureka District, Nevada. U. S. National Museum, Catalogue Nos. 56819*g*, 56819*h*, and 56819*i*, respectively.

Figures 10, 11, 12, and 13 are copied from Walcott, 1884, pl. 21, figs. 2, 4, 3, and 6, respectively, where the forms are labeled *Olenellus howelli.*

14. A cephalon with short eye lobes, occular ridges, and normal genal angles. Natural size. Locality (52), Prospect Mountain, Eureka District, Nevada. U. S. National Museum, Catalogue No. 56819*j*.

Figure 14 is copied from Walcott, 1884, pl. 9, fig. 15, where it is labeled *Olenellus howelli.*

15. A cephalon without distinct occular ridge connecting the glabella and eye lobes. Natural size. Locality (52), Prospect Mountain, Eureka District, Nevada. U. S. National Museum, Catalogue No. 56819*k*.

Figure 15 is copied from Walcott, 1884, pl. 21, fig. 5, where it is labeled *Olenellus howelli.*

16. A cephalon 9 mm. in length that has the outline shown by fig. 12 but with the eyes close to the glabella. Natural size. Locality (52), Prospect Mountain, Eureka District, Nevada. U. S. National Museum, Catalogue No. 56819*l*.

Figure 16 is copied from Walcott, 1884, pl. 9, fig. 15*a*, where it is labeled *Olenellus howelli.*

17. A narrow, convex, cephalon with elongate eye lobes of the adult type and with genal angles advanced as in small cephalons shown by figs. 11 and 12. Natural size. Locality (51), Prospect Mountain, Eureka District, Nevada. U. S. National Museum, Catalogue No. 56819*m*.

18. Cephalon with the genal spine on the left side in advance of that on the right side. Natural size. Locality (52), Eureka District, Nevada. U. S. National Museum, Catalogue No. 56819*n*.

Olenellus fremonti, new species (continued): PAGE

19. Broad form of cephalon with the same characters as that shown by fig. 17. Natural size. Locality (52), Eureka District, Nevada. U. S. National Museum, Catalogue No. 56819*o*.

    Figures 17, 18, and 19 are copied from Walcott, 1884, pl. 21, figs. 7, 9, and 8, respectively, where the forms are labeled *Olenellus howelli.*

20. Outline of a small weathered specimen of a minute cephalon that is doubtfully referred to this species from locality (313*g*), Groom District, south end of Timpahute Range, between Nye and Lincoln Counties, Nevada. U. S. National Museum, Catalogue No. 56823*a*.

    Figure 20 is copied from Walcott, 1886, pl. 19, fig. *2e,* where it is labeled *Olenellus gilberti.*

21. Hypostoma ($\times$ 3) associated with the cephalons represented by figs. 10-19 at locality (52), Eureka District, Nevada. U. S. National Museum, Catalogue No. 56819*p*.

22. Hypostoma associated with specimens of the cephalon of this species at locality (176), Deep Spring Valley, California. Natural size. U. S. National Museum, Catalogue No. 56820*b*.

DESCRIPTION OF PLATE 38

Olenellus canadensis, new species.................................... 316

FIG. 1. A large cephalon, partially restored in outline. The intergenal angle is not usually present in this species. Natural size. Locality (35*h*), Mt. Bosworth, British Columbia. U. S. National Museum, Catalogue No. 56814*a*.

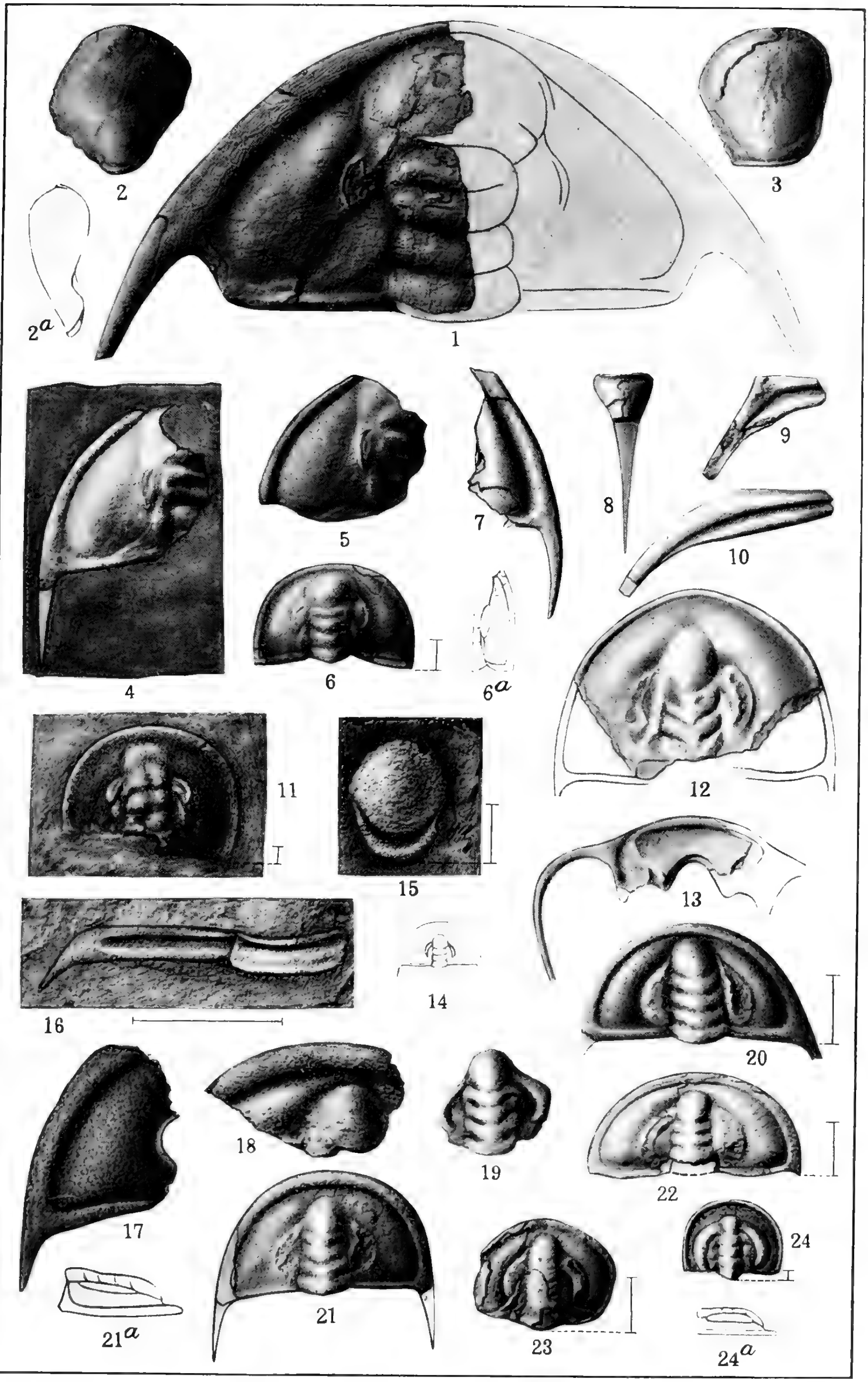
2 and 3. Illustrations of the hypostoma found associated with the cephalon. Natural size. 2 = locality (35*h*), Mt. Bosworth; 3 = locality (35*f*), Mt. Stephen; both in British Columbia. *2a* shows the convexity of the hypostoma. U. S. National Museum, Catalogue Nos. 56815*a* and 56814*b*, respectively.

4. Fragment of a cephalon, showing the genal angle extending into a spine. Natural size. Locality (35*h*), Mt. Bosworth, British Columbia. U. S. National Museum, Catalogue No. 56814*c*.

5. Fragment of a cephalon, showing the eye lobe and tubercle back of it. Natural size. Locality (35*h*), Mt. Bosworth, British Columbia. U. S. National Museum, Catalogue No. 56814*d*.

6 and 6*a*. A small cephalon in which the marginal border is narrow. $\times$ 3. Locality (35*h*), Mt. Bosworth, British Columbia. U. S. National Museum, Catalogue No. 56814*e*.

7. Fragments of a side of a cephalon with genal spine preserved. Natural size. Locality (35*f*), Mt. Stephen, British Columbia. U. S. National Museum, Catalogue No. 56815*b*.



LOWER CAMBRIAN TRILOBITES

Olenellus canadensis, new species (continued): PAGE

8. Fragment of the telson. Natural size. Locality (35*h*), Mt. Bosworth, British Columbia. U. S. National Museum, Catalogue No. 56814*f*.

9 and 10. Fragments of the pleural lobe of thoracic segments. Natural size. 9 = locality 58*y*; 10 = locality 35*h*; both on Mt. Bosworth, British Columbia. U. S. National Museum, Catalogue Nos. 56816*a* and 56814*g*, respectively.

11. A minute cephalon associated with this species and referred to it. × 8. Locality (35*l*), Ptarmigan Pass, Alberta. U. S. National Museum, Catalogue No. 56817*a*.

Callavia ? nevadensis, new species 285

FIG. 12. Portion of a cephalon showing the broad frontal limb, narrow glabella, and relatively short eye lobe as compared with *Olenellus gilberti*. Natural size. Locality (52), Prospect Mountain, Eureka District, Nevada. U. S. National Museum, Catalogue No. 56799*a*.

Figure 12 is copied from Walcott, 1884, pl. 9, fig. 16, where this specimen is referred to *Olenellus gilberti*.

13. Fragments of the under side of a cephalon in which the genal angles are carried far forward as in *O. fremonti* (pl. 37, figs. 8-12). Natural size. Locality (313*g*), south end of Timpahute Range, Nevada. U. S. National Museum, Catalogue No. 56800*a*.

Figure 13 is copied from Walcott, 1886, pl. 19, fig. 2*d*, where the specimen is referred to *Olenellus gilberti*.

14. Outline of a small cephalon showing broad frontal limb and normal type of genal angles. Natural size. Locality (51), summit of Prospect Mountain, Eureka District, Nevada. U. S. National Museum, Catalogue No. 56799*b*.

Figure 14 copied from Walcott, 1884, pl. 21, fig. 13, where the specimen is referred to *Olenellus gilberti*.

Wanneria ? gracile, new genus and new species 298

FIG. 15. An hypostoma associated with specimens of the cephalon of this species. × 2. Locality (177), west of Deep Spring Valley, Inyo County, California. U. S. National Museum, Catalogue No. 56802*a*.

16. A thoracic segment associated with the hypostoma illustrated by fig. 15. This has the pleural furrow of *Wanneria* but the spinous termination is more like that of *Holmia*. Same locality as fig. 15. U. S. National Museum, Catalogue No. 56802*b*.

17. Left side of cephalon showing strong border, and slender genal spine. × 1.5. U. S. National Museum, Catalogue No. 56803*a*.

18. Fragment of the front part of the cephalon. × 1.5. U. S. National Museum, Catalogue No. 56803*b*.

Wanneria ? gracile, new genus and new species (continued): PAGE

19. Central part of the cephalon illustrating the glabella and palpebral lobes. Natural size. U. S. National Museum, Catalogue No. 56803*c*.

20. A cephalon slightly distorted by lateral compression. × 1.5. U. S. National Museum, Catalogue No. 56803*d*.

    The specimens illustrated by figs. 17-20 are from locality (60*b*), the sandstones at Vermilion Pass, Alberta.

21. A cast in a fine quartzitic sandstone from California of a very perfect cephalon showing the heavy marginal border and the slender glabella. Natural size. Locality (14*p*), near Resting Springs, Inyo County, California. U. S. National Museum, Catalogue No. 56804*a*.

22. A cephalon that appears to have the adult characters of the species. × 1.5. U. S. National Museum, Catalogue No. 56805*a*.

23. Central portion of the cephalon of a small specimen in which the genal angles are rounded inward. × 2. U. S. National Museum, Catalogue No. 56805*b*.

24. A minute cephalon exclusive of spines. × 10. U. S. National Museum, Catalogue No. 56804*b*.

    Figures 22-24 represent specimens from locality (1*v*), a fine arenaceous shale at Barrel Spring, Silver Peak Quadrangle, Esmeralda County, Nevada.

DESCRIPTION OF PLATE 39

Olenellus lapworthi Peach.................................... 331

Fig. 1. Dorsal shield. × 2. Specimen in Royal Scottish Museum, Edinburgh, Scotland, Catalogue No. M4080*d*. Cast in U. S. National Museum, Catalogue No. 56830*a*.

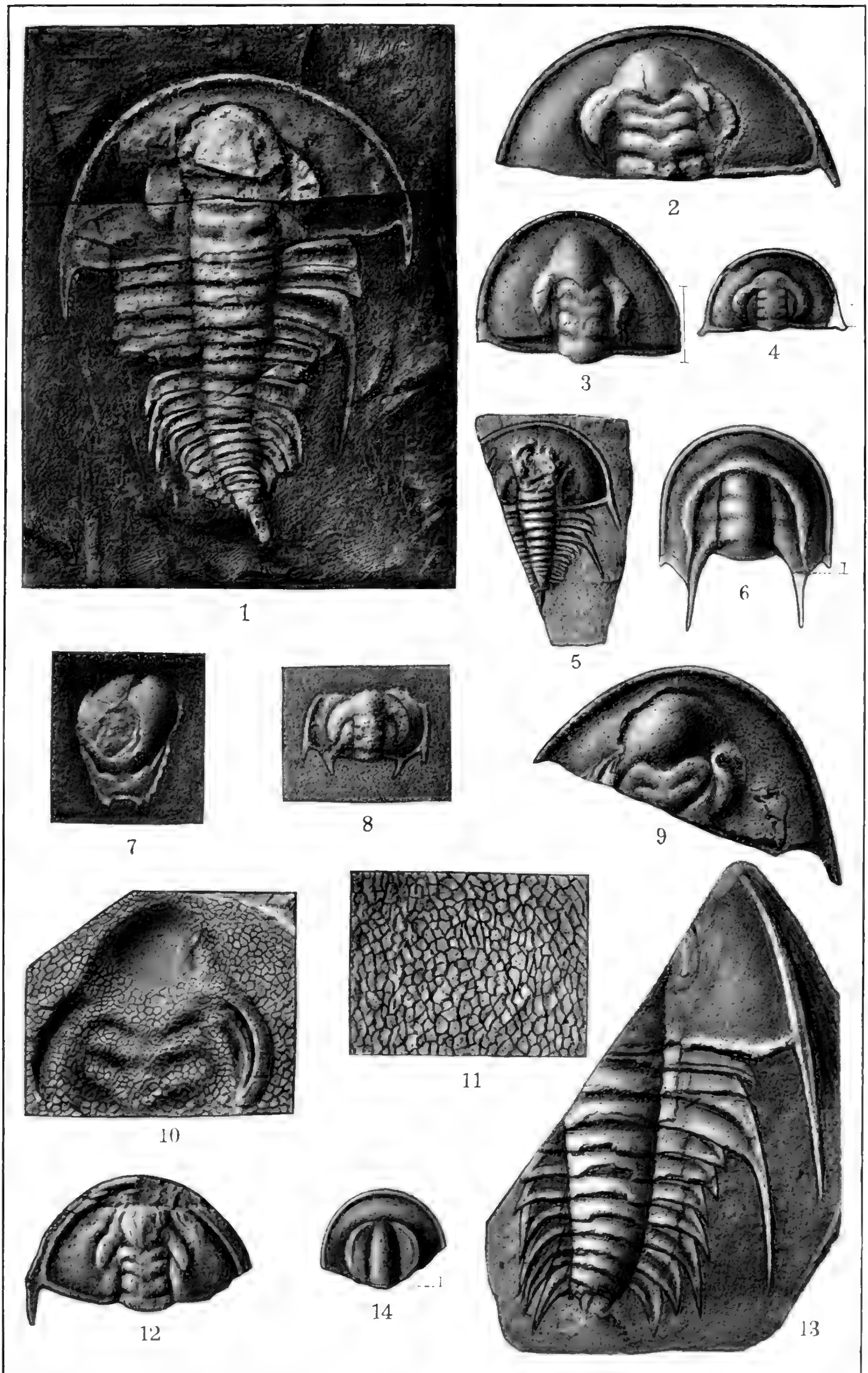
   Figure 1 is redrawn from the specimen figured by Peach, 1894, pl. 29, fig. 3.

2. Cephalon. × 1.5. Specimen in Royal Scottish Museum, Edinburgh, Scotland, Catalogue No. M495*f*. Cast in U. S. National Museum, Catalogue No. 56830*b*.

3. Cephalon. × 2. U. S. National Museum, Catalogue No. 56831*a*.

4. A small cephalon. Specimen in Royal Scottish Museum, Edinburgh, Scotland, Catalogue No. M2611*e*. Cast in U. S. National Museum, Catalogue No. 56830*c*.

5. Imperfect dorsal shield, 6.25 mm. in length. × 3. Specimen in Royal Scottish Museum, Edinburgh, Scotland, Catalogue No. M4198*d*. Cast in U. S. National Museum, Catalogue No. 56830*d*.



LOWER CAMBRIAN TRILOBITES

Olenellus lapworthi Peach (continued): PAGE

6. Cephalon 1.2 mm. in length. × 15. Specimen in Royal Scottish Museum, Edinburgh, Scotland, Catalogue No. M515*f*. Cast in U. S. National Museum, Catalogue No. 56830*e*.

7. Hypostoma associated with this species. × 3. Specimen in Royal Scottish Museum, Edinburgh, Scotland, Catalogue No. M494*f*. Cast in U. S. National Museum, Catalogue No. 56830*f*.
The specimens represented by figures 1-7 are all from shales on the northern slope of Meal a' Ghubhais, 1,200 to 1,300 feet above Loch Maree, Ross-shire, Scotland.

Olenellus reticulatus Peach.. 335

FIG. 8. Small, broken cephalon. × 8. Specimen in Royal Scottish Museum, Edinburgh, Scotland, Catalogue No. M510*f*. Cast in U. S. National Museum, Catalogue No. 56834*a*.

9. Portion of cephalon. Natural size. Specimen in Royal Scottish Museum, Edinburgh, Scotland, Catalogue No. M4076*d*. Cast in U. S. National Museum, Catalogue No. 56834*b*.
Figure 9 is redrawn from the specimen illustrated by Peach, 1894, pl. 30, fig. 1.

10. Photographic enlargement (× 1.5) of a portion of the cephalon figured by Peach, 1894, pl. 30, fig. 2. Specimen in Royal Scottish Museum, Edinburgh, Scotland, Catalogue No. M4104*d*. Cast in U. S. National Museum, Catalogue No. 56834*c*.
The specimen is compressed laterally so as to force the eye lobes in toward the glabella.

11. Portion of the surface of the specimen represented in fig. 10. × 3.

12. Cephalon with short palpebral lobe and strong outer border. × 2. Specimen in Royal Scottish Museum, Edinburgh, Scotland, Catalogue No. M4141*d*. Cast in U. S. National Museum, Catalogue No. 56834*d*.

13. Portions of cephalon and thorax. × 2. Specimen in Royal Scottish Museum, Edinburgh, Scotland. Cast in U. S. National Museum, Catalogue No. 56834*e*.
The specimens represented by figures 8-13 are all from shales on the northern slope of Meal a' Ghubhais, 1,200 to 1,300 feet above Loch Maree, Ross-shire, Scotland.

Olenellus?, sp. undt.. 342

FIG. 14. A minute cephalon from the same locality as that given for *Olenellus lapworthi* and *O. reticulatus*. × 10. Specimen in Royal Scottish Museum, Edinburgh, Scotland, Catalogue No. M4157*d*. Cast in U. S. National Museum, Catalogue No. 56838*a*.

DESCRIPTION OF PLATE 40

PAGE

Olenellus gigas Peach 323

FIG. 1. The type specimen. Natural size. From the northern slope of Meal a' Ghubhais, above Loch Maree, Ross-shire, Scotland. Specimen in Royal Scottish Museum, Edinburgh, Scotland. Cast in U. S. National Museum, Catalogue No. 56824*a*.

Figure 1 is drawn from the specimen represented by Peach, 1894, p. 667, fig. 1.

Olenelloides armatus Peach 347

FIG. 2. Cephalon 2.5 mm. in length (× 6) from the same locality as *Olenellus gigas*. *xx* = intergenal spines. *aa* = genal spines. Specimen in the Royal Scottish Museum, Edinburgh, Scotland, Catalogue No. M2636*e*. Cast in U. S. National Museum, Catalogue No. 56839*a*.

3. Natural matrix of an entire specimen 5 mm. in length (× 5) from the same locality as *Olenellus gigas*. Specimen in the Royal Scottish Museum, Edinburgh, Scotland, Catalogue No. M4201*d*. Cast in U. S. National Museum, Catalogue No. 56839*b*.

A matrix of a small dorsal shield of *Olenellus lapworthi* occurs on the same piece of shale and is shown on the left side.

Holmia lundgreni Moberg 290

FIGS. 4 and 4*a*. Drawn from a plaster cast of the cephalon represented by Moberg, 1899, pl. 14, figs. 2*a-b*. Natural size. Original in the collection of the Geologic Institution of the University of Lund, Sweden. Cast in the U. S. National Museum, Catalogue No. 24630*a*.

5. Central portions of a cephalon showing glabella very distinctly. Natural size. U. S. National Museum, Catalogue No. 24630*b*.

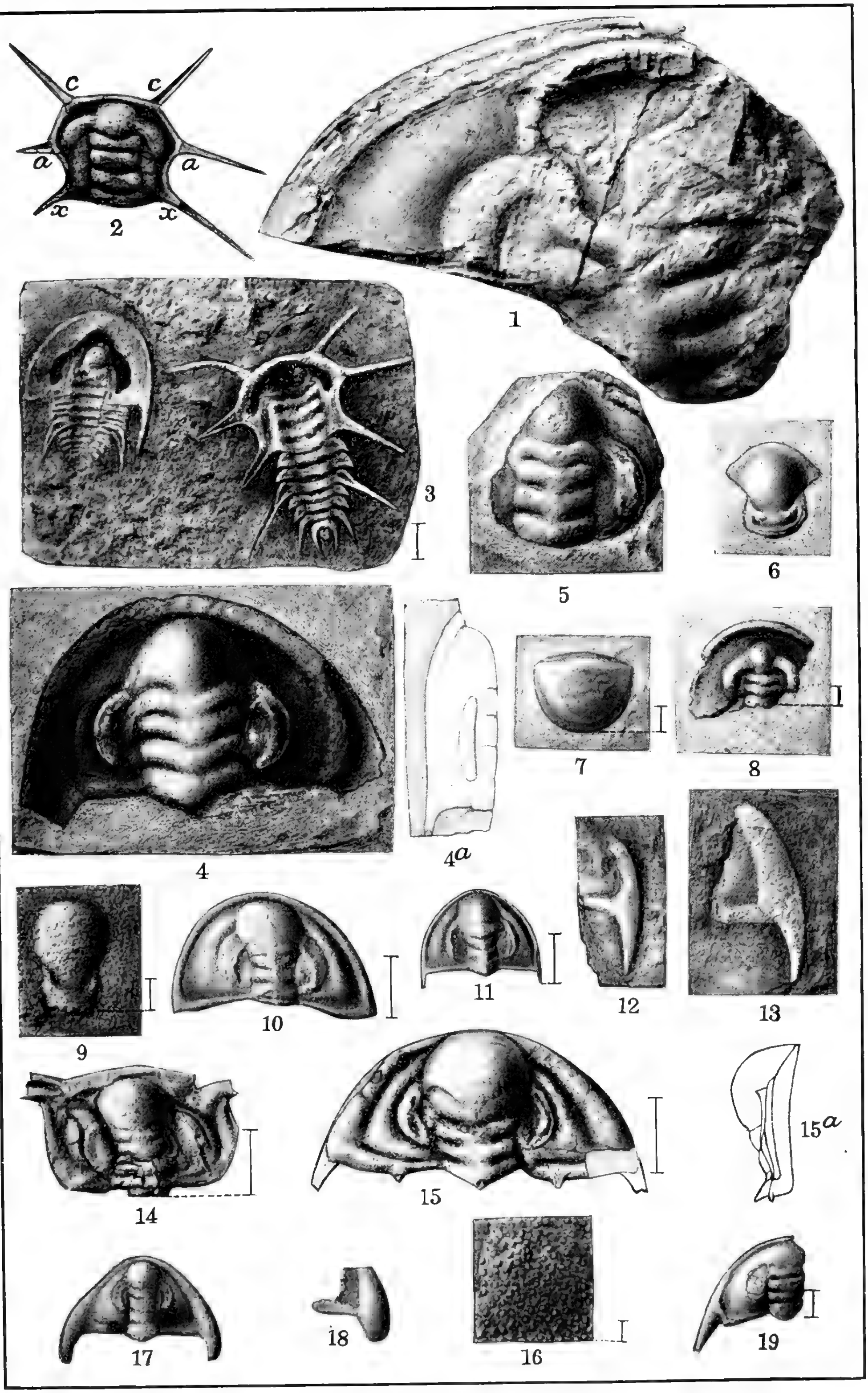
6. An hypostoma illustrated from a cast taken in a natural mould. Natural size. U. S. National Museum, Catalogue No. 24630*c*.

7. Pygidium. × 3. The test is exfoliated. U. S. National Museum, Catalogue No. 24630*d*.

The specimens represented by figs. 4 to 7 are from locality (390*v*), near Tunbyholm, Sweden.

Olenellus gilberti var. 331

FIG. 8. Fragment of a cephalon (× 4) associated with *Olenellus canadenis* and *O. gilberti*. Locality (35*l*), Ptarmigan Pass, Alberta. U. S. National Museum, Catalogue No. 56830*a*.



LOWER CAMBRIAN TRILOBITES

PAGE

Olenellus ? claytoni, new species.................................. 319

FIG. 9. An hypostoma associated with this species. The back margin appears to be denticulated. $\times 4$. Locality (1*k*). U. S. National Museum, Catalogue No. 56813*a*.

10. A cephalon flattened by compression in arenaceous shale. $\times 2$. Locality (1*i*). U. S. National Museum, Catalogue No. 56813*b*.

11. A cephalon slightly distorted by lateral compression. $\times 2$. Locality (1*i*). U. S. National Museum, Catalogue No. 56813*c*.

The specimens represented by figs. 9 to 11 are from localities (1*i* and 1*k*), both near Barrel Spring, Silver Peak Quadrangle, Nevada.

Olenellus argentus, new species.................................. 314

FIG. 12. Under side of genal spine showing rounded doublure. Natural size. U. S. National Museum, Catalogue No. 56812*a*.

13. Dorsal view of a genal spine and portions of the marginal borders and broad cheek. Natural size. U. S. National Museum, Catalogue No. 56812*b*.

14. A small head with the genal angle on a line with the front of the glabella. $\times 2$. U. S. National Museum, Catalogue No. 56812*c*.

15 and 15*a*. Top view and side outline of a cephalon, showing the heavy marginal rim and large spherical anterior lobe of the glabella. $\times 2$. U. S. National Museum, Catalogue No. 56812*d*.

16. Enlargement of the surface. $\times 6$. U. S. National Museum, Catalogue No. 56812*e*.

The specimens represented by figs. 12 to 17 are from locality (1*v*), 3 miles north of Valcalda Spring, Esmeralda County, Nevada.

Peachella iddingsi (Walcott).................................. 343

FIG. 17. Illustration of the type specimen of the species. $\times 2$. U. S. National Museum, Catalogue No. 15407*a*.

This specimen was first figured by Walcott, 1884, pl. 9, fig. 12. In both instances the broken portions have been restored from other specimens.

18. Under side of a genal spine and connected parts of the cheek. Natural size. U. S. National Museum, Catalogue No. 15407*b*.

19. A small cephalon, $\times 2$, with a more slender spine than that of the larger cephalon represented by fig. 17. U. S. National Museum, Catalogue No. 15407*c*.

The specimens represented by figs. 17-19 are from locality (52), Prospect Peak, Eureka District, Nevada.

DESCRIPTION OF PLATE 41

PAGE

Olenellus cf. *gilberti* (See pl. 36).[1]

FIG. 1. A large cephalon showing the cast of the inner surface of the cheek and with the left side restored beyond the broken line. Natural size. Compare with figs. 3 and 16, pl. 36; also with fig. 2, pl. 39. Cast in U. S. National Museum, Catalogue No. 56833*a*.

2. A small cephalon. × 2. Cast in U. S. National Museum, Catalogue No. 56833*b*.

3. A broken cephalon preserving the left palpebral lobe. Natural size. Cast in U. S. National Museum, Catalogue No. 56833*c*.

4. A telson referred to this species. × 3. Cast in U. S. National Museum, Catalogue No. 56833*d*.

The four specimens represented by figs. 1-4 are from the conglomerate limestone at Bic, and are now in the Museum of the Geological Survey of Canada.

Olenellus logani, new species 333

FIGS. 5, 5*a*, and 5*b*. Top, side, and front views of a small and very perfect cephalon. Top view × 6, other views × 2.5. Cast in U. S. National Museum, Catalogue No. 56832*a*.

6. A cephalon × 2, with right side restored in outline. Cast in U. S. National Museum, Catalogue No. 56832*b*.
(See note under fig. 7.)

Pædeumias transitans, new genus and new species (See pls. 24, 25, 32, 33, 34, and 44) 305

FIG. 7. Top and side views of a large cephalon. Natural size. Cast in U. S. National Museum, Catalogue No. 56842*a*.

The specimens represented by figs. 5, 6, and 7 are from l'Anse au Loup, Labrador, and are now in the Museum of the Geological Survey of Canada (5 = catalogue No. 414*d*; 6 = 414*e*; and 7 = 416).

Olenellus fremonti, new species (See pl. 37) 320

FIG. 8. Enlargement of the specimen represented by fig. 9, pl. 37, to show surface, glabellar lobes, and union of palpebral ridges with glabella. × 6. U. S. National Museum, Catalogue No. 56819*e*.

Callavia bicensis, new species 277

FIGS. 9 and 9*a*. Top and side views (× 1.5) of a cephalon and 5 thoracic segments from locality (2*r*), 2 miles west of Bic, Quebec, Canada. U. S. National Museum, Catalogue No. 56794*a*.

Callavia, sp. undt 279

FIGS. 10 and 10*a*. Ends of pleuræ (× 2) associated with the specimen represented by figs. 9 and 9*a*. U. S. National Museum, Catalogue Nos. 56843*a* and 56843*b*, respectively.

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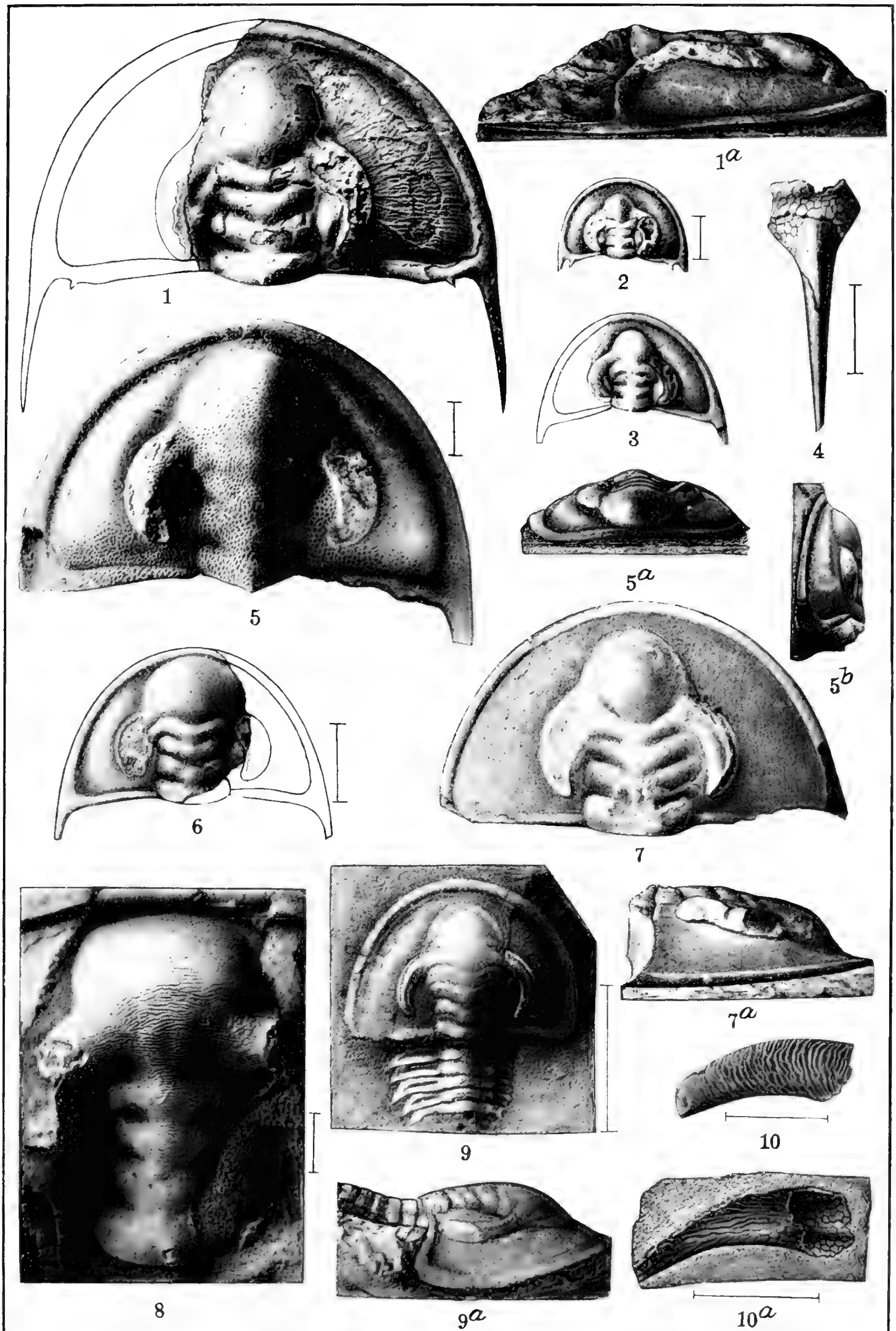
[1] No reference to this form occurs in the text.



LOWER CAMBRIAN TRILOBITES

DESCRIPTION OF PLATE 42

PAGE

Callavia callavei Lapworth 282

FIG. 1. The right hand side of this figure is a photograph of a specimen natural size. The left side is a photograph of the same specimen reversed and joined to the other with great care from measurements of the glabella. The central part of the cheek was broken out and has been recemented, as also the posterior of the two cracks across the margin. The cheek is slightly bent downwards along a line running about midway between the glabella and lateral margin; when this is allowed for, the head is 3 to 4 mm. wider. The very oblique lighting gives a false impression of strength to the 3d and 4th glabellar furrows.

Original in the collection of the University Museum, Birmingham, England. Cast in the U. S. National Museum, Catalogue No. 56796*a*, to which it was presented by Mr. Frank Raw.

This specimen was collected in Comley quarry, on Little Caradoc, near Church Stretton, Central Shropshire, England.

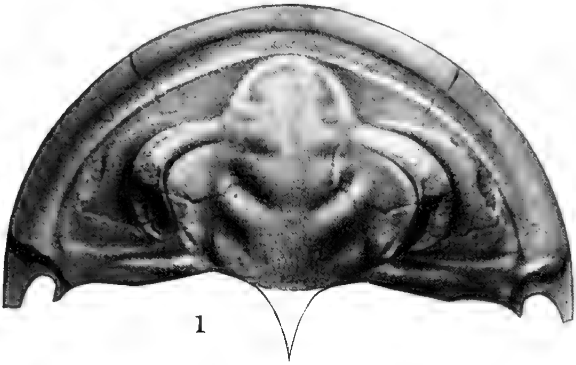
2. Side view of cephalon represented in fig. 1 showing the convexity, form of the glabella, cheek, border, and intergenal spine. Natural size.

Callavia cartlandi Raw (MS.) 282

FIG. 3. The type specimen

4. Side view of the specimen represented by fig. 3. Natural size.

The specimen represented by figs. 3 and 4 was collected at the same locality as the specimen of *Callavia callavei* represented in figs. 1 and 2. Original in the collection of the University Museum, Birmingham, England. Cast in the U. S. National Museum, Catalogue No. 56797*a*, to which it was presented by Mr. Frank Raw.



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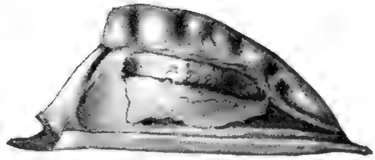

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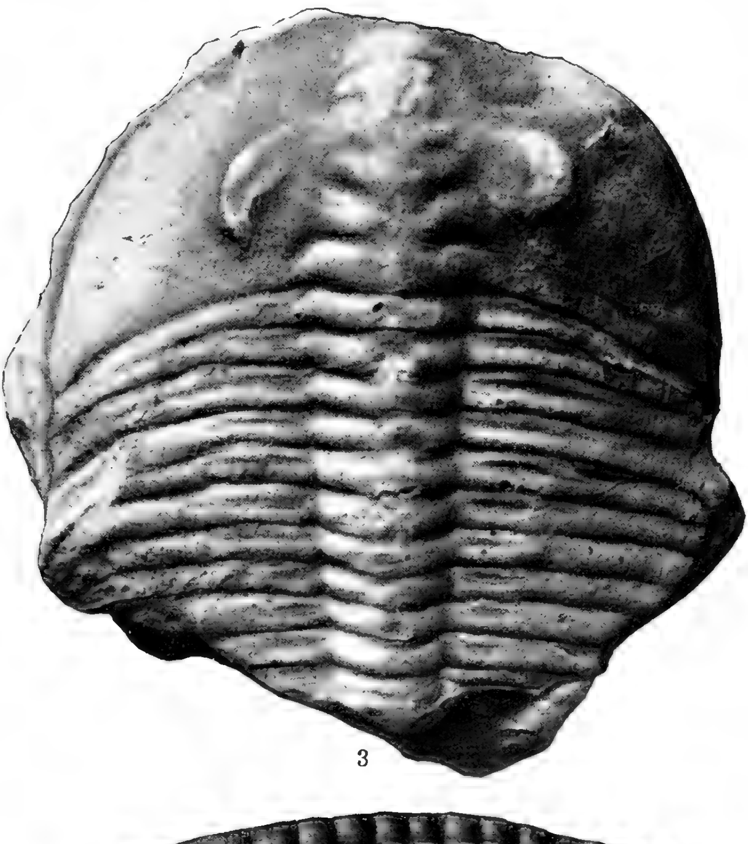

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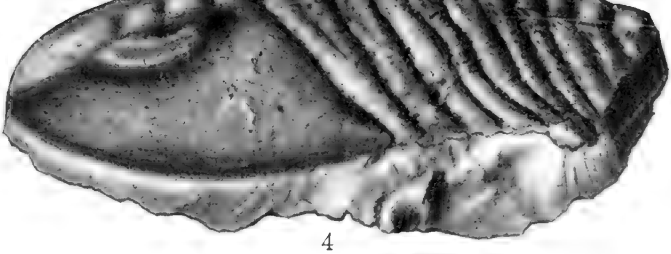


4

LOWER CAMBRIAN TRILOBITES

DESCRIPTION OF PLATE 43

PAGE

Limulus polyphemus 239

FIG. 1. Inner surface of the test of the eye of adult *Limulus* showing cones with a minute opening at the apex. $\times 6$. The sharp apex of the cones is shown near the edges where they are seen more in profile.

2. Exterior of the same eye of which the interior is shown by fig. 1. The pits and ridges of the test between them is finely shown. $\times 7$.

3. A portion of the outer surface of the eye represented by fig. 2 enlarged to 25 diameters.

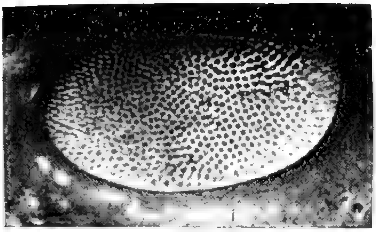
4. Enlargement of the outer surface of the eye on a cephalon 7 mm. in length. $\times 25$. This represents the eye in a younger stage of growth than that represented by figs. 2 and 3 where the pits have ridges between them that are flatter and broader and more like those of *Olenellus gilberti* as shown by fig. 5.

Olenellus gilberti Meek (See pl. 36)................................ 239

FIG. 5. Enlargement of the visual surface, palpebral lobe, and portion of the glabella, $\times 75$, of the cephalon represented by fig. 6. There are 42 openings on the portion of the visual surface exposed. These openings and the ridges separating them are similar in appearance to those of the eye of young specimens of *Limulus polyphemus* as shown by fig. 4.

6. A small cephalon. $\times 50$. The right eye of this is shown in fig. 5.

The specimen represented by figs. 5 and 6 is from the limestone at (35*l*), Ptarmigan Pass, Alberta (see pl. 36, figs. 11-16). U. S. National Museum, Catalogue No. 56828*f*.



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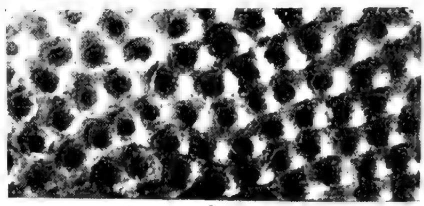

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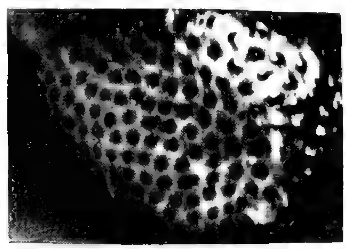

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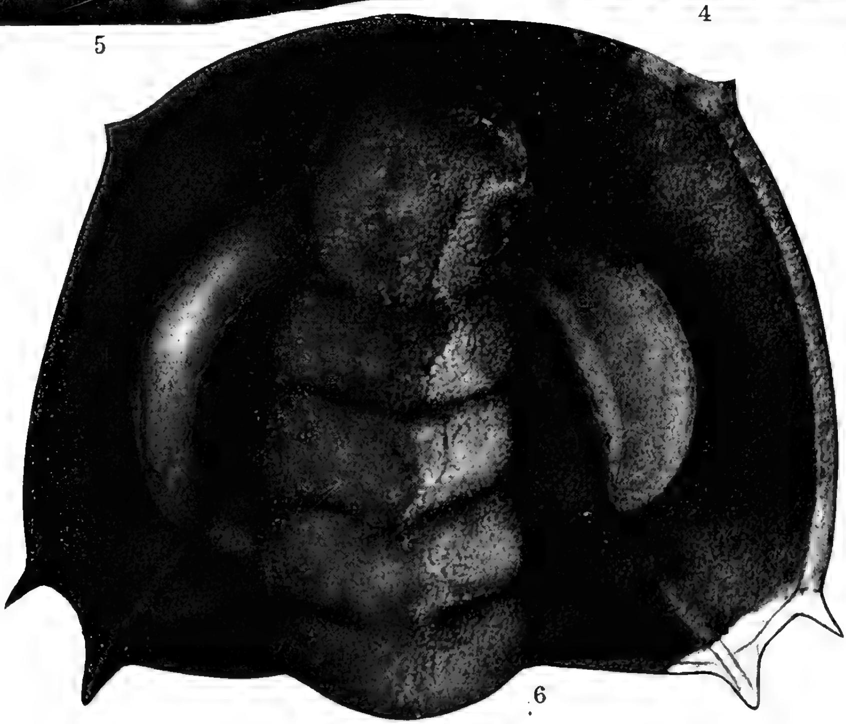


6

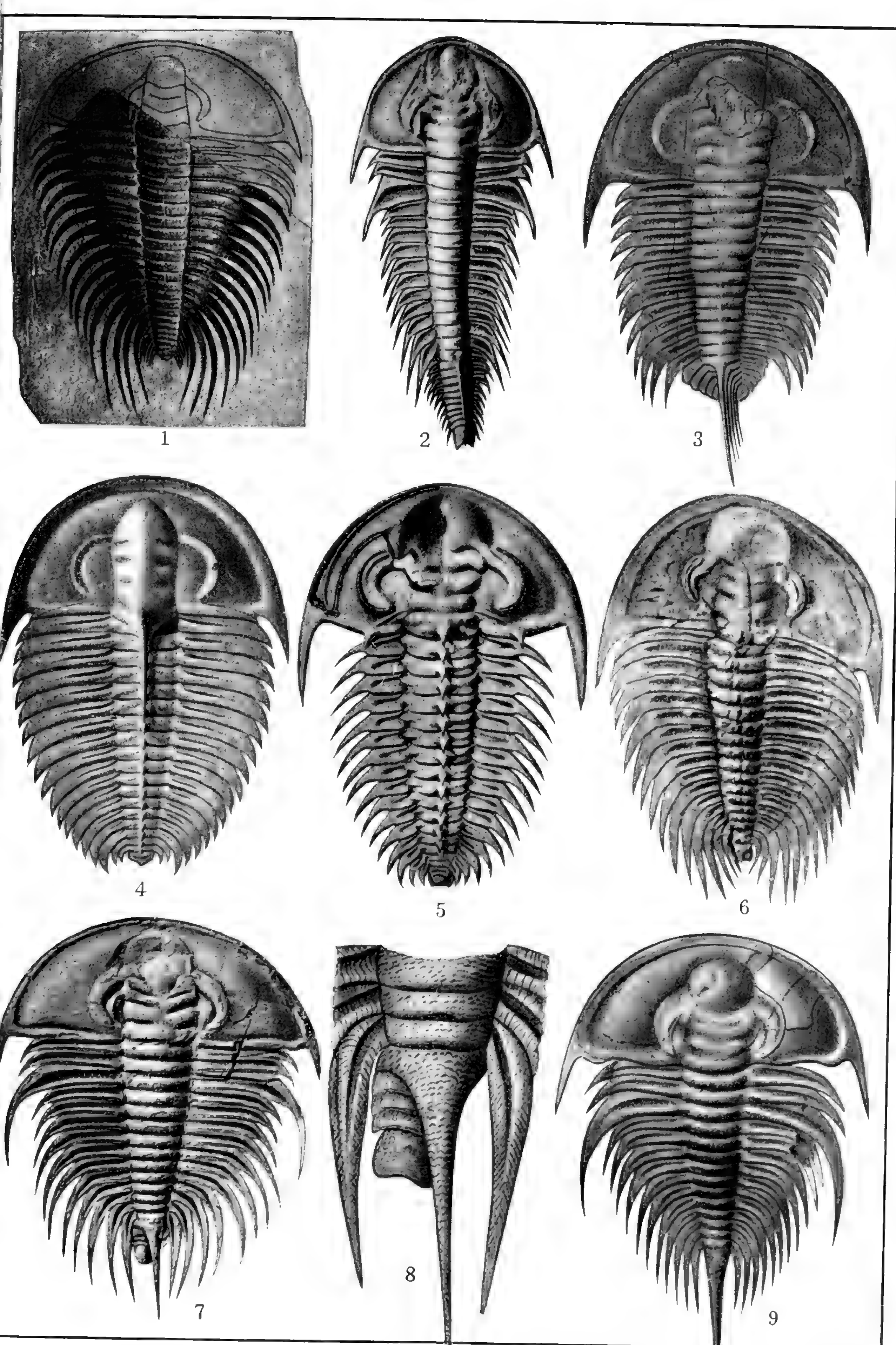
LOWER CAMBRIAN TRILOBITES

DESCRIPTION OF PLATE 44

		PAGE
Fig. 1.	*Nevadia weeksi* Walcott (pl. 23)	257
2.	*Mesonacis vermontana* (Hall) (pl. 26)	264
3.	*Elliptocephala asaphoides* Emmons (pl. 24)	269
4.	*Callavia bröggeri* (Walcott) (pl. 27)	279
5.	*Holmia kjerulfi* (Linnarsson) (pl. 27)	288
6.	*Wanneria walcottanus* (Wanner) (pl. 30)	302
7.	*Pædeumias transitans* Walcott (pl. 33)	305
8.	*Pædeumias transitans* Walcott (pl. 33) Enlargement of the posterior portion of fig. 7 showing the rudimentary segments and pygidium beneath the telson-like segment.	305
9.	*Olenellus thompsoni* Hall (pl. 35)	336

The above series of figures is reproduced in order to illustrate the variation in the principal genera of the Mesonacidæ, also in order that the student may at a glance note the changes from the most primitive form *Nevadia* (fig. 1) through one line of descent, as represented by figs. 2, 3, and 7, to *Olenellus* (fig. 9).

On another line of descent the figures serve to illustrate through figs. 1, 3, 4, 5, and 6 the probable line of descent from *Nevadia* (fig. 1) to *Holmia* (fig. 5) and on to *Paradoxides*.



LOWER CAMBRIAN TRILOBITES

INDEX

NOTE.—The first reference to each of the species described in this paper gives the page upon which the description begins and the figure references. References to the description of certain parts or features of a species are only given in the index if the description occurs outside of the detailed description of the species. For instance: the description of the pygidium of a certain species will be found in the description of that species and there will be no specific reference in the index to the pygidium unless it is described or discussed at some other point in the paper.

The list on pages 351-371 may be regarded as a completely cross-referenced index to the synonymy in this paper, and only the actual references as they occur in the synonymy will be found in this index.

SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 53, NUMBER 7

CAMBRIAN GEOLOGY AND PALEONTOLOGY

No. 7.—PRE-CAMBRIAN ROCKS OF THE BOW RIVER VALLEY, ALBERTA, CANADA

WITH THREE PLATES

BY

CHARLES D. WALCOTT

(Publication 1939)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
August, 1910

WASHINGTON, D. C.
PRESS OF JUDD & DETWEILER, INC.
1910

CAMBRIAN GEOLOGY AND PALEONTOLOGY

No. 7.—PRE-CAMBRIAN ROCKS OF THE BOW RIVER VALLEY, ALBERTA, CANADA

By CHARLES D. WALCOTT

(With Three Plates)

Contents

Illustrations

INTRODUCTION

During the summer of 1909 I continued my study of 1907[1] on the Cambrian formations of the main range of the Rocky Mountains on the line of Bow Valley, in Alberta, with the view of discovering a base to the Fairview formation of the Lower Cambrian, and, if possible, of finding fossils in the shales and sandstones beneath that formation in the Bow Valley. When measuring the Cambrian sandstone on the northeast slopes of Mount Fairview and Saddle Mountain, about 2.5 miles southwest of Laggan, a fine quartz conglomerate about 100 feet in thickness was found, and below it a gentle, forest-

[1] Smithsonian Miscellaneous Collections, vol. 53, No. 5, 1908, Cambrian Sections of the Cordilleran Area, pp. 204–217.

covered débris slope without rock outcrops. Knowing that there were shales and sandstones in the Bow Valley to the northwest, I went up on the slopes of Mount Saint Piran, and from there examined with a strong field-glass the valley and mountains to the northeast. I could see that the Fairview sandstone formed a cliff on Mount Hector and Fort Mountain above slopes that were evidently clear of débris, and that there was a marked change in the character of the rock where the cliff and slope met. A week was next spent at Fort Mountain and vicinity, and, with the information secured there as to the presence of a massive bedded conglomerate at the base of the Fairview formation, a trip was made along the southwest side of Bow Valley in search of contacts between the basal conglomerate and the shales beneath. It was found that the lower slopes and bottom of Bow Valley from Hector Lake to the vicinity of Cascade Station, on the Canadian Pacific Railway, were underlain by pre-Cambrian shales and sandstone formations, to which the names Hector and Corral Creek are applied in this paper. These rocks were formerly referred to the Bow River group of the Cambrian by Mr. R. G. McConnell.[2]

TOPOGRAPHY OF BOW VALLEY

The Bow Valley heads at Bow Pass, and for the first 10 miles of its course it appears to be deeply excavated in the limestones and sandstones of the Cambrian formations. Southeast of Bow Peak the floor of the valley attains a width of two miles; it is joined from the west by the flat of Hector Lake, and from this point the valley is broadly U-shaped in profile, with high mountain fronts on either side. This is illustrated by figure 1, plate 45. This profile is continued to the southeast for about 35 miles to where the ridges of the Sawback Range and the mass of Pilot Mountain on the north, and of Mount Bourgeau on the south, crowd the sides of the valley toward the river; from here to Banff it is deep and narrow. The valley is evidently one of pre-glacial origin that has been widened and shaped by the passage of a great glacier into which lateral glaciers flowed from the side canyons. Rounded hills and ridges of gravel and clay record glacial deposits and subsequent stream erosion.

I find in my field note-book the following: "The view from Fairview Mountain, 3,000 feet above Lake Louise, is a most extended

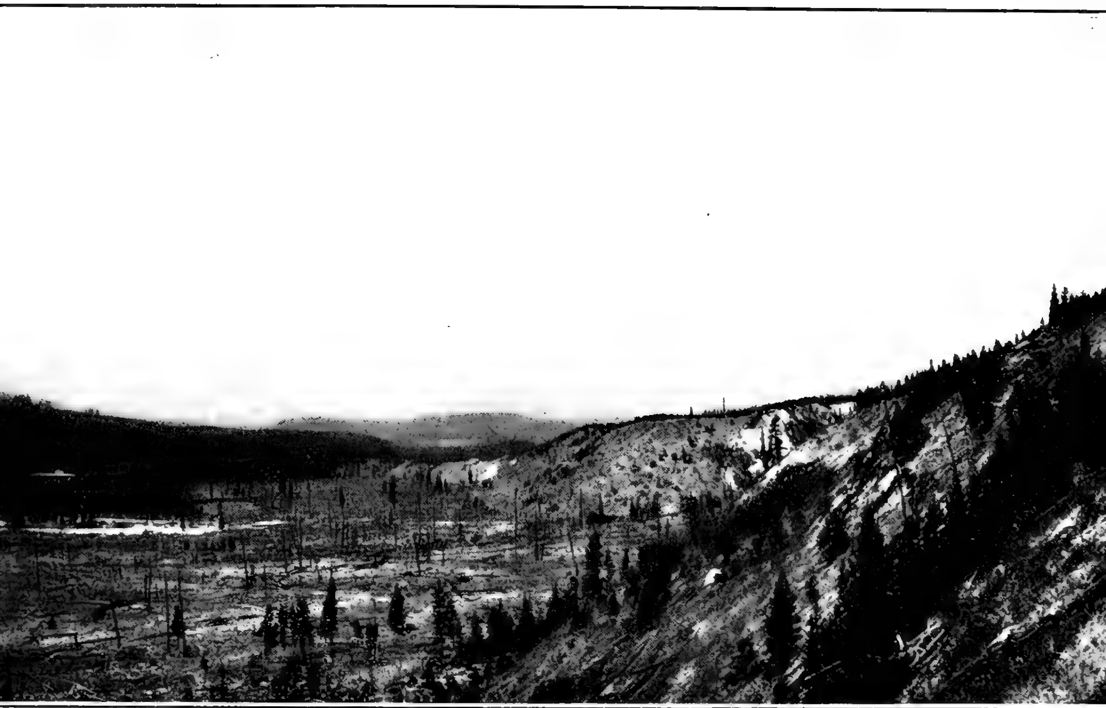
[2] Annual Rept., Geol. and Nat. Hist. Survey Canada, for 1886, Part D, p. 15 D, 1887.

Fig. 1. PANORAMIC VIEW LOOKING ACROSS THE BOW VALLEY FROM T

is view shows on the left Mount Aberdeen and the Victoria Glacier, Mounts Whyte and St. Piran, and to
(Photograph b

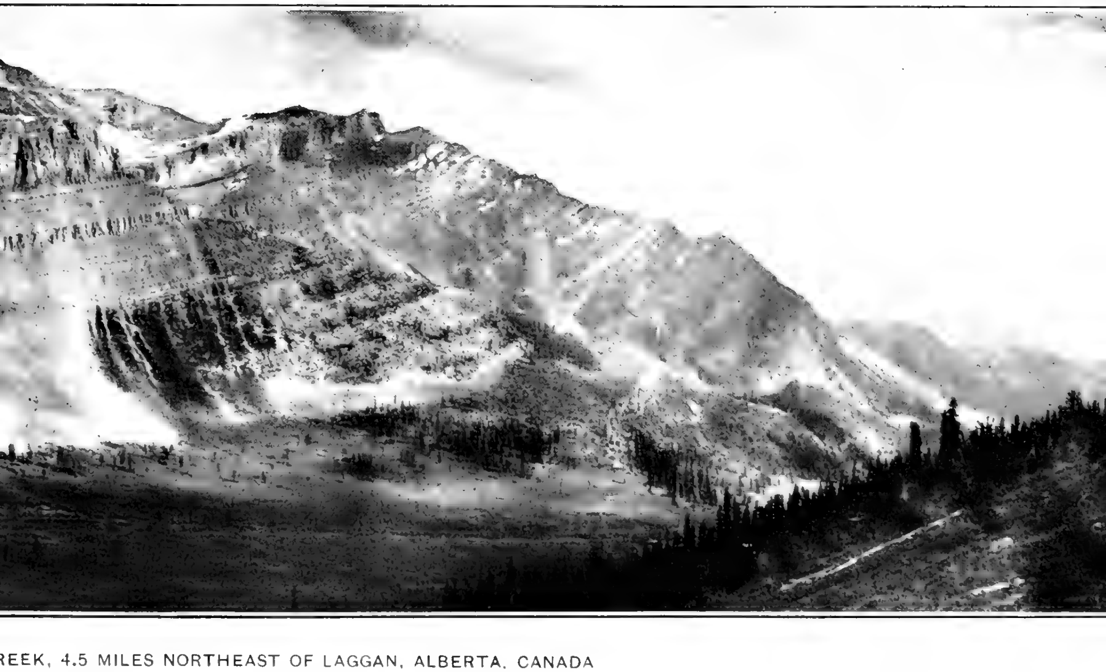
Fig. 2. VIEW OF FORT MOUNTAIN FROM THE WEST SIDE OF CO

e high, massive Cambrian limestone cliffs of the upper half of the mountain and the broken sandstone cliffs bel
by C. D.



V HILLS ABOUT 2 MILES NORTHEAST OF LAGGAN, ALBERTA, CANADA

t of the center Mounts Bosworth and Daly, also in the foreground the broad, almost flat, bottom of the valley. Walcott, 1909.)

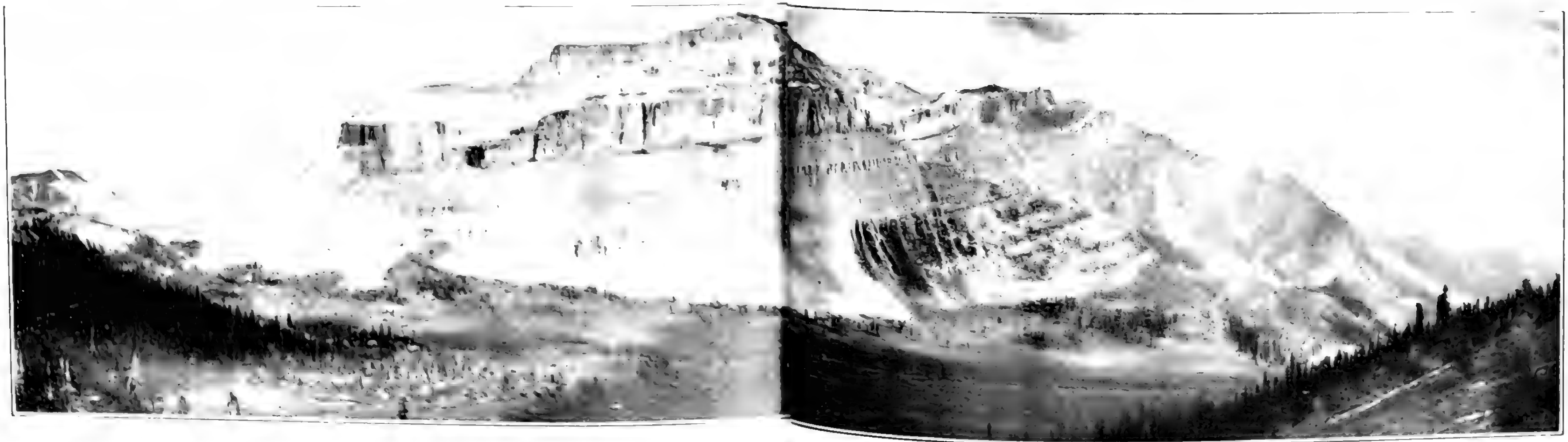


REEK, 4.5 MILES NORTHEAST OF LAGGAN, ALBERTA, CANADA

rast strongly with the rounded hills and slopes of pre-Cambrian rocks shown by figure 1, plate 46. (Photograph , 1909.)

... PANORAMIC VIEW LOOKING ACROSS THE BOW VALLEY FROM THOW HILLS ABOUT 2 MILES NORTHEAST OF LAGGAN, ALBERTA, CANADA

... ight of the center Mounts Bosworth and Daly, also in the foreground ... (Walcott, 1900.)



... VIEW OF FORT MOUNTAIN ... CREEK 4.5 MILES NORTHEAST OF LAGGAN, ALBERTA, CANADA

The high massive ... ntrast strongly with the rounded hills and ... 1909.)

and beautiful one. To the north and far below lies the broad valley of the Bow, which stretches to the southeast toward Banff and northwest to the beautiful Hector Lake. Rising above the valley on the northeast rugged mountains extend in massive ridges and high peaks from Mount Hector to Mount Richardson, and southeastward to the great wall of Castle Mountain and the serrated Sawback Range. Farther to the southeast are the high points of the Bourgeau Range west of Banff, and beginning with Mount Temple and arching to the south and southwest there is a superb panorama of high mountains, glaciers, and crested walls, such as is rarely seen in any land. As a study in glaciation and topographic forms it is unexcelled, and is well worth a journey across the continent to see."

Panoramic photographs taken from high on the mountains on both sides of the valley show that the valley has been excavated on the northeast slope of a broad, broken anticlinal arch. The general average height of the peaks and ridges as they are massed against the horizon indicates a base-leveling of the region prior to the period of uplift and erosion that has developed the present topography.

The topographic forms resulting from the erosion of the Cambrian rocks are well shown on all the higher mountains adjoining the valley—Mounts Temple, Aberdeen, Victoria, and Hector. Fort (fig. 2, pl. 45) and Castle mountains are capped by high, precipitous cliffs of limestone underlain by alternating slopes of shale and broken cliffs of sandstone for 2,000 feet or more down to the low cliff formed by the Fairview sandstone or its basal conglomerate. Below this cliff the pre-Cambrian shales and sandstones form smooth slopes and irregular, rounded hills and ridges with bands of gray, purple, and greenish shales. These are well shown southeast of Mount Hector and the ridges south of Mount Richardson and Fort Mountain (fig. 2, pl. 46). The contrast of topographic form between the Cambrian and pre-Cambrian rocks is finely illustrated by Fort Mountain (fig. 2, pl. 45) and the area just south of it (fig. 2, pl. 46), and it first led me to suspect the presence of pre-Cambrian rocks in this area.

BASAL CAMBRIAN ROCKS

The conglomerate at the base of the Fairview formation is massive bedded and usually formed of small quartz pebbles in a coarse sandstone matrix. At Fort Mountain it is over 300 feet thick and extends northwest and southeast for a long distance. The white quartz pebbles here vary from 2 mm. to 10 cm. in diameter (average 10-15 mm.), and are mixed near the base of the conglomerate with rounded

and angular pebbles (fragments) of the dark siliceous shales of the subjacent Hector formation; also of the siliceous and hard greenish shale that occurs from 520-640 feet below, and the reddish and chocolate-colored, arenaceous shale 640 feet or more below the base of the Cambrian.

Two and one-half miles north of Fort Mountain, at the east foot of Ptarmigan Peak, the basal conglomerate is only 170 feet thick, while on Mount Temple, 8 miles southeast of Fort Mountain, it is represented by a few thin layers of fine conglomerate interbedded in a massive-bedded, fine-grained sandstone.

On the north slope of Vermilion Pass, east of Boom Mountain, 11 miles southeast of Mount Temple, the conglomerate occurs in massive beds that form a series 200 feet and more in thickness.

The variation in thickness of the basal Cambrian conglomerate seems to indicate that the pre-Cambrian surface over which it was deposited was broadly irregular.

UNCONFORMITY BETWEEN THE CAMBRIAN AND THE PRE-CAMBRIAN ROCKS

Viewed in a restricted way, much of the pre-Cambrian surface was regular and the Cambrian rocks appear to be conformable to the subjacent pre-Cambrian strata. All about the sides of the valley the strata of the two formations, Fairview of the Cambrian and Hector of the Algonkian, dip away at about the same angle, but, when we apply the test of the varying thickness of the basal Cambrian conglomerate and the difference in the character of the upper beds of the Algonkian in different places, we at once become aware that the pre-Cambrian surface is more or less irregular, and that when the Cambrian sea transgressed over the area now included in the Bow Valley it found a broadly irregular surface with low hills and broad level spaces covered with a deep mantle of disintegrated rock. It washed out the muds and carried them away and deposited the sand and pebbles of its advancing beaches over and around the irregularities of the pre-Cambrian surface.

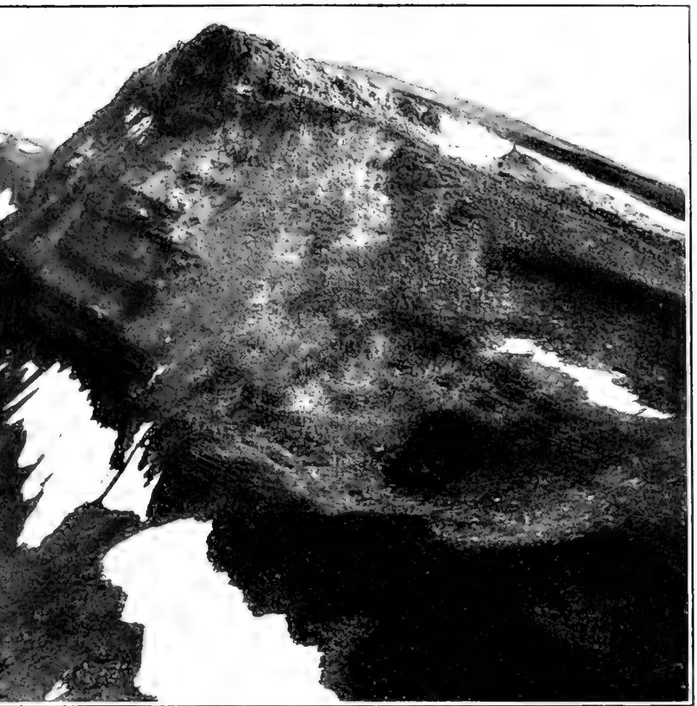
The unconformity is well shown at Fort Mountain, where the basal Cambrian is formed of massive layers 4-10 feet thick, which usually rest directly on the Hector shale (pre-Cambrian). In places, however, slight hollows in the shale are filled with thin layers of a more or less ferruginous sandstone that was deposited by gentle currents prior to the deposition of the massive conglomerate layers. The lower 10-20 feet of this conglomerate contains rounded and

Fig. 1. VIEW FROM THE NORTH OF THE RIDGE SOUTHEAST OF THE LOW
NORTHEAST OF LAG

The upper edge of the snow banks about half way down the slope of th
the pre-Cambrian arenaceous shales of the Hecto

Fig. 2. PANORAMIC VIEW FROM THE SOUTH SLOPE OF FORT MOUNTAIN LOOKING TO THE SO

e lower dark cliff in the mountain on the left is formed by the basal conglomerate of the Cambrian. Below, t
sandstones of the Corral Creek formation overlain by the shales of the Hector formation. In the distance on
900.)



OF PTARMIGAN LAKE AND NORTHEAST OF FORT MOUNTAIN, 6 MILES
BERTA, CANADA

marks the line of contact of the Cambrian basal conglomerate with
tion. (Photograph by C. D. Walcott, 1909.)

AST AND SOUTH FROM A POINT 4 MILES NORTHEAST OF LAGGAN, ALBERTA, CANADA

pe is formed of the arenaceous shales of the Hector formation. The rounded hills in the foreground are forme
ht are the high peaks of the Bow Range on the southwest side of the Bow Valley. (Photograph by C. D. Wal

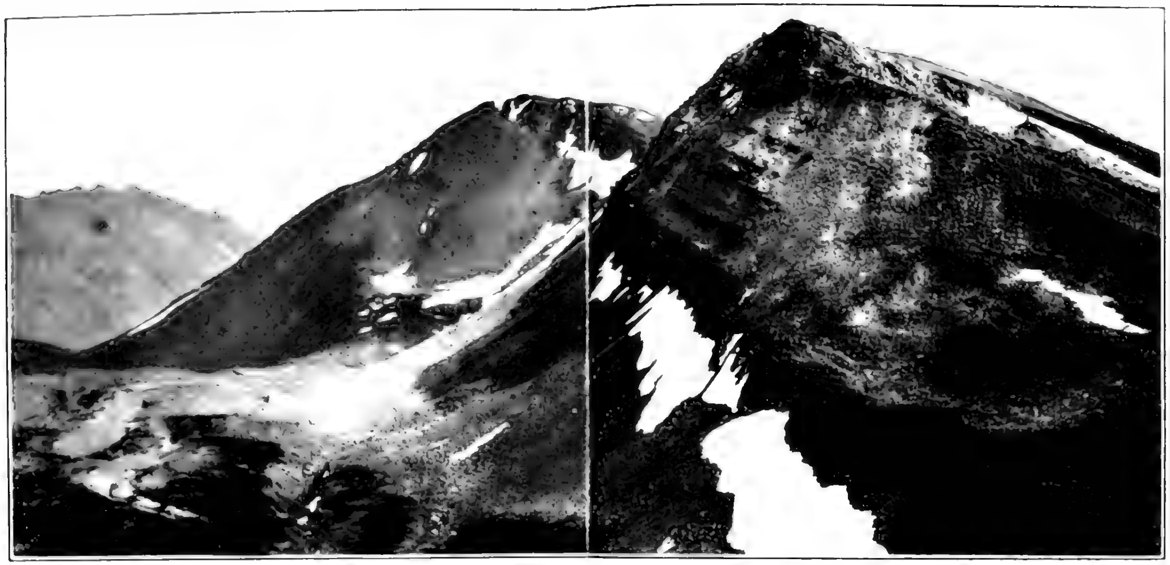


FIG. 1. VIEW FROM THE NORTH OF THE RIDGE SOUTHEAST OF THE LOWER END OF PTARMIGAN LAKE AND NORTHEAST OF FORT MOUNTAIN, 6 MILES NORTHEAST OF LAGGAN, ALBERTA, CANADA

The inner edge of the snow banks about half way down the slope of the ridge marks the line of contact of the Cambrian basal conglomerate with [illegible] pre-Cambrian arenaceous shale of the Hector formation. (Photograph by C. D. Walcott, [illegible])

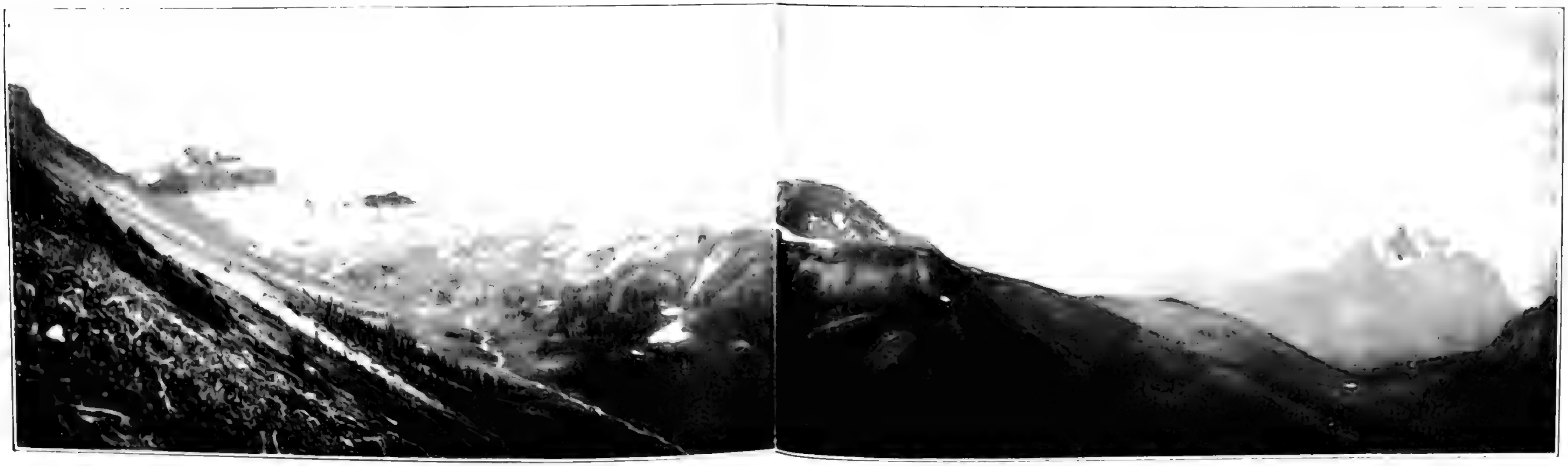


FIG. 2. PANORAMIC VIEW FROM THE SOUTH SLOPE OF FORT MOUNTAIN LOOKING [illegible] THE [illegible]THEAST AND SOUTH FROM A POINT 4 MILES NORTHEAST OF LAGGAN, ALBERTA, CANADA

The lower dark cliff in the mounta[illegible] is formed by the basal conglomerate [illegible] of the sandstones of the Corral Creek [illegible] Hector [illegible] cott, 1909.)

angular fragments of the subjacent pre-Cambrian formations (fig. 1, pl. 46). The Cambrian sea was evidently transgressing across the dark siliceous shales of the pre-Cambrian land and reducing them to rolled pebbles, angular fragments, and mud. The mud gave origin to small lentiles of shale similar in character to the shale below the unconformity, while lentiles of sandstone of greenish tint indicate that fine material was being derived from still older pre-Cambrian formations than the shale.

On the southwest side of the Bow Valley the Fairview formation extends well down on the wooded slopes, but I know of no exposure showing the contact of its basal conglomerate with the underlying Hector shale north of Mount Temple. East of Mount Bosworth the contact of the Cambrian and pre-Cambrian appears to be in the valley just north of Stephen on the Continental Divide.

Of greater importance is the evidence that the sediments of the two periods were deposited under different physical conditions. The Cambrian sandstones are composed of clean, well-washed grains, and the Cambrian calcareous and argillaceous shales were deposited as muds offshore along with the remains of an abundant marine life. The Hector shales of the pre-Cambrian are siliceous and without traces of life; the sandstones are impure and dirty, with the quartz grains a dead milky white, or glassy and iron stained. The sediments forming them were evidently deposited in relatively quiet muddy waters, and I think in fresh or brackish waters.[3]

I do not compare the limestone formations, as they are 2,000 feet or more above the plane of unconformity in the Cambrian, and below the Hector-Corral Creek series in the Algonkian.

PRE-CAMBRIAN ROCKS

The distribution of the pre-Cambrian rocks in the Bow Valley is outlined on the accompanying map (pl. 47). They extend throughout the bottom and lower slopes of the valley from Bow Peak to Cascade, on the Canadian Pacific Railway, about 7 miles west of Banff. East of Mount Hector and in the Mount Richardson-Ptarmigan Peak mass they rise in high hills both east and west of Pipestone River, and continue eastward across Corral and Baker creeks before passing beneath the Cambrian, on the south slopes of Castle Mountain.

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[3] This view will be presented more fully in a paper on "The Abrupt Appearance of the Cambrian Fauna in North America" that I have prepared for presentation at the meeting of the International Geological Congress at Stockholm in August, 1910.

At the south end of Fort Mountain the descending section beneath the Cambrian conglomerate is as follows, as measured on the east side of Corral Creek Canyon, 4 miles northeast of Laggan:

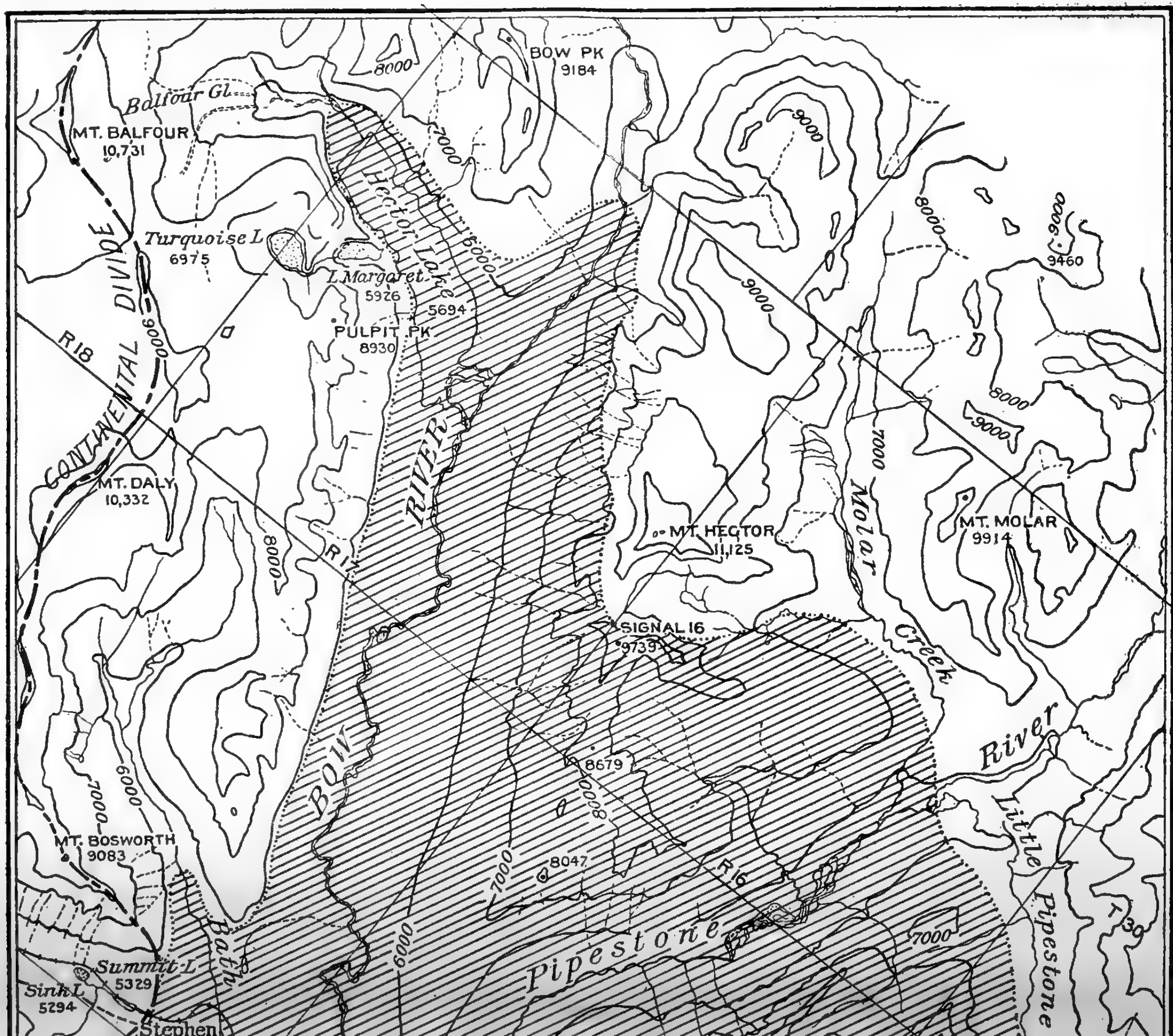
CAMBRIAN CONGLOMERATE

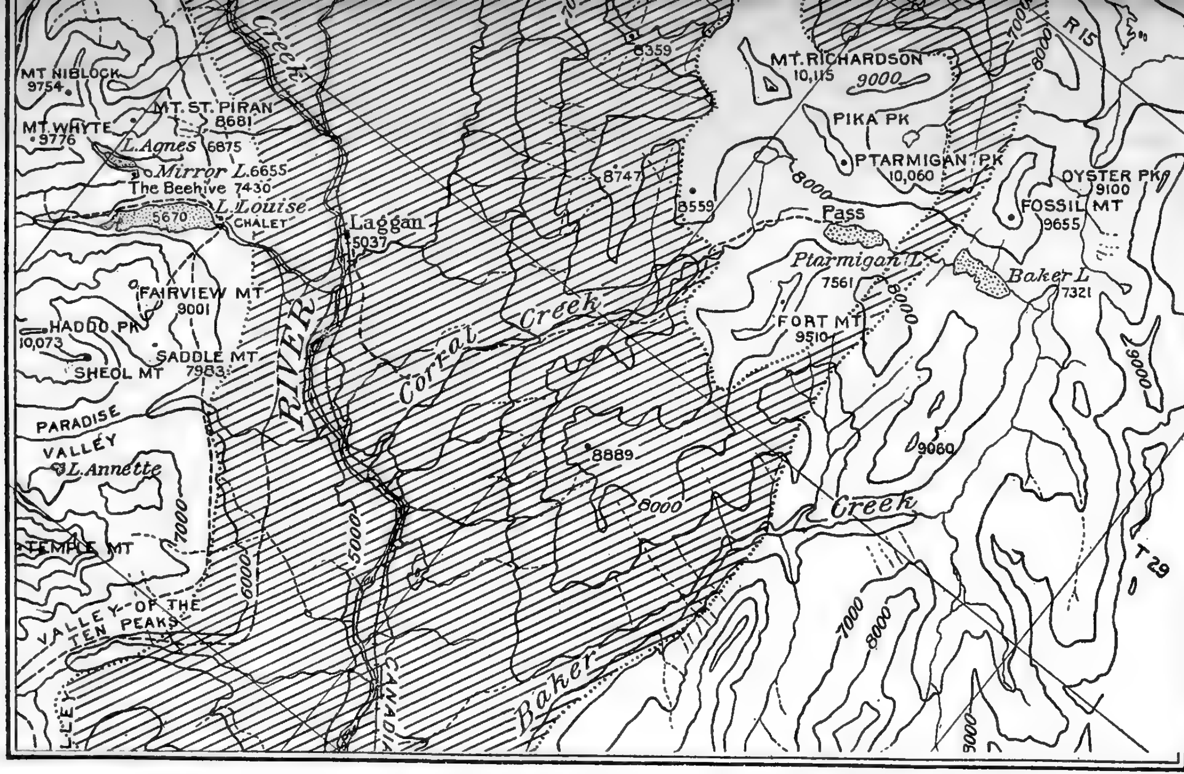
Unconformity

ALGONKIAN

	Feet
HECTOR FORMATION:	
1. Dark-gray to black, finely arenaceous (siliceous) shale breaking down on weathered slopes, or sometimes forming low ragged cliffs beneath conglomerate. Upper surface slightly eroded..	520
2. Greenish, finely arenaceous shale, with bands of reddish-colored shale. At 110 feet down a layer of fine interformational conglomerate occurs, with a finely arenaceous, greenish-colored matrix that includes thin layers of pinkish, compact limestone that weathers more rapidly than the matrix..................	120
3. Purple-colored, finely arenaceous or siliceous shale............	140
4. Greenish-colored, finely arenaceous or siliceous shale..........	40
5. Massive-bedded conglomerate. Matrix a coarse sandstone, with quartz pebbles and fragments of gray pinkish limestone.....	27
This is evidently a deposit made from material brought down by a river reaching back into the hills of that epoch. The presence of the limestone is very important, as it indicates limestones below any exposures of the pre-Cambrian rocks of the Bow Valley. In places the matrix is coarse-grained and in others a fine-grained sandstone. The limestone fragments are small and those of sandstone usually larger, some being 12 inches across.	
6. Reddish purple, arenaceous, siliceous shale, with greenish bands.	455
This shale is widely distributed and often folded and broken in exposures along the valley.	
CORRAL CREEK FORMATION:	
1. Coarse-grained, light-gray sandstone in massive layers, with some of the layers a fine quartz conglomerate. Estimated...	120
The outcrop of this bed is usually concealed by débris.	
2. Hard, quartzitic sandstones that break down on exposure to weather. Estimated....................................	1,200+
An anticline and general disturbance of the strata at this point breaks the downward continuity of the section.	

On the west side of Corral Creek Valley and south of the syncline of Cambrian limestones and sandstones of Mount Richardson and Ptarmigan Peak the strata of the Hector and Corral Creek formations are displaced by thrusts and folds, so that the section is broken and imperfect. The same is true of the pre-Cambrian formations south of the base of Fort Mountain.


BOW PK
9184
Balfour Gl.
MT. BALFOUR
10,731
Turquoise L
6975
L. Margaret
5926
5694
Hector Lake
PULPIT PK
8930
CONTINENTAL DIVIDE
R18
R17
R16
T30
MT. DALY
10,332
BOW RIVER
MT. HECTOR
11,125
Molar Creek
MT. MOLAR
9914
9460
SIGNAL 16
9739
8679
8047
River
Little Pipestone
Pipestone
MT. BOSWORTH
9083
Bath
Summit L
5329
Sink L
5294
Stephen
6000
7000
8000
9000

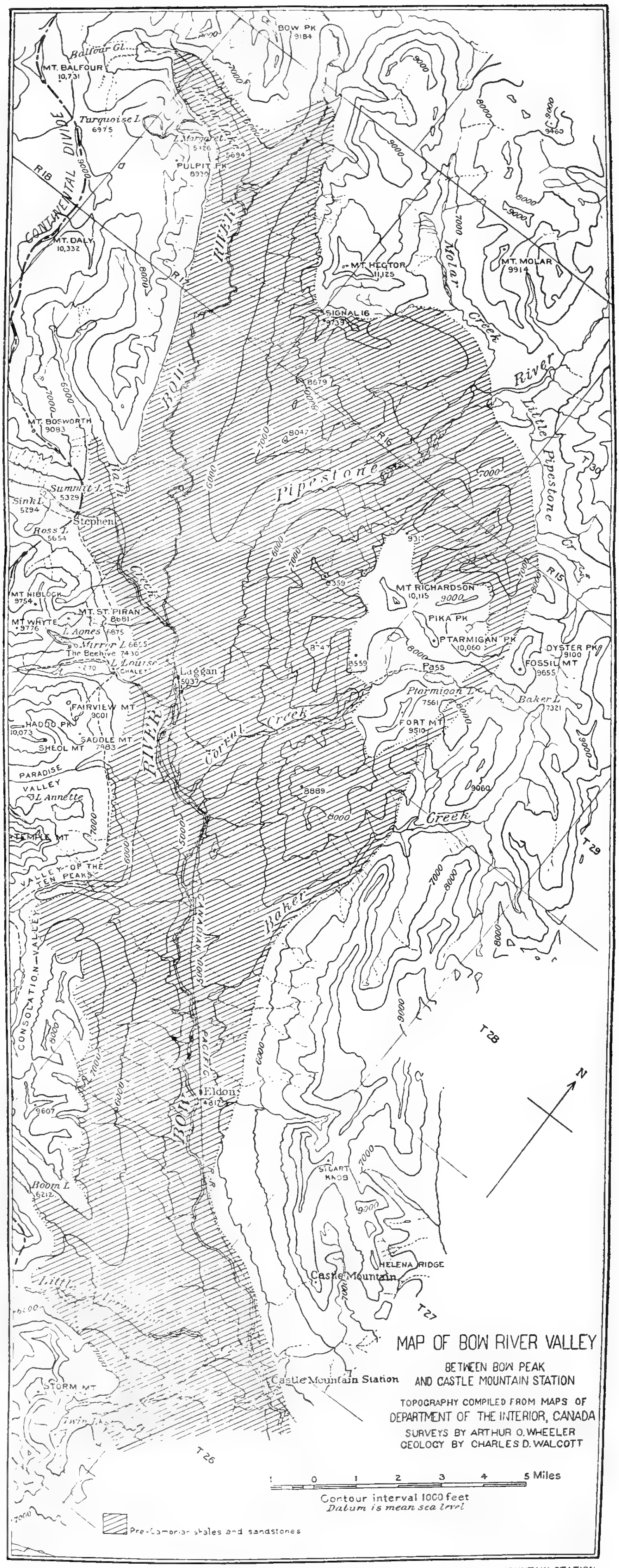


MAP OF THE PORTION OF THE BOW VALLEY EXTENDING FROM BOW PEAK SOUTHEAST TO CASTLE MOUNTAIN STATION, JUST BELOW LITTLE VERMILION CREEK

The boundary lines of the pre-Cambrian formations are put in from reconnaissance observation and are subject to minor modification, especially on the northeast toward Little Pipestone Creek.

Except on the northeast, where the Silurian and Devonian rocks of the Sawback Range come in contact with the Algonkian, the entire area is surrounded by overlying Cambrian rocks.

The extension beyond the map to the southeast is outlined on the north by the slopes a little north of the railroad track as far as the vicinity of Cascade, and on the south by Copper and Pilot mountains. No Algonkian rocks were observed east of Cascade.



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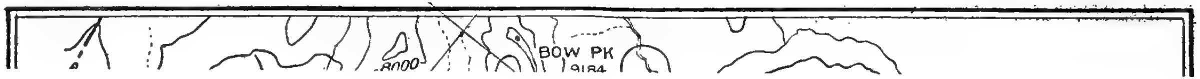
8000
BOW PK
9184

RÉSUMÉ

	Feet	
HECTOR FORMATION:		
1. Dark-gray shale	520	
2. Greenish shale, with narrow bands of reddish purple shale	120	
3. Purple shale	140	
4. Greenish shale	40	
5. Conglomerate	27	
6. Purple shale	455	
Total		1,302
CORRAL CREEK FORMATION:		
1. Sandstone (estimated)	120	
2. Sandstones (estimated)	1,200	
Total		1,320
Total section		2,622

At the east base of Ptarmigan Peak, 2.5 miles north of the Fort Mountain section, the Hector shales and conglomerate beneath the basal conglomerate of the Cambrian are essentially the same as on the south end of Fort Mountain, except that the green and purple shales are closer to the Cambrian, owing to the thickness of dark gray shale being less. Opposite the head of Baker Lake the pre-Cambrian shales and subjacent compact, hard sandstones are thrust over the Siluro-Devonian, arenaceous limestones.

The relations of the basal conglomerate and the pre-Cambrian are well shown north of Ptarmigan Peak; also at the north foot of Fort Mountain.

On the northeast ridge of Mount Temple and northwest of the Valley of the Ten Peaks the downward section is as follows:

CAMBRIAN CONGLOMERATE

Unconformity

ALGONKIAN

	Feet
HECTOR FORMATION:	
1. Hard, steel gray, siliceous shales in thin lamellæ, with interbedded siliceous layers, varying from thin shale to an inch in thickness	145
2. Flaggy, compact, finely arenaceous beds	480
3. Greenish, compact, slaty, siliceous shales, with a few thin layers of hard dove-colored to pinkish limestone. [This is about the same horizon as the interformational conglomerate in No. 2, of the Fort Mountain section.]	255

	Feet
4. Shales similar to those of No. 3, with purple and greenish bands	65
5. Shales similar to those of No. 3, of a dark-purple color	590
6. Massive-bedded conglomerate, with coarse sandstone matrix, pebbles of white quartz, gray and yellowish buff sandstone, green siliceous shale, and rolled fragments of a reddish purple, jaspery, siliceous rock	365
7. Greenish, compact, siliceous, slaty shales	250+
Total	2,150+

Below No. 7 there are more shales and then a series of compact, hard quartzitic sandstones of the Corral Creek formation, as seen south of Fort Mountain. The sandstones are not well exposed in the Mount Temple section.

At Vermilion Pass a gray saponaceous, siliceous shale occurs beneath the basal Cambrian conglomerate, and outcrops of purple-colored shales occur low down on the northeast slope of Boom Mountain.

On Bath Creek, along the line of the Canadian Pacific Railway, west of Laggan, outcrops of tilted and folded, arenaceous, purple shales occur, and at various points in the broad valley of the Bow the shales and sandstones of the Hector? formation may be seen. Usually, however, the floor of the valley is covered with the gravels, sand, and clays of the drift.

CORRELATION OF BOW VALLEY PRE-CAMBRIAN ROCKS WITH THOSE OF NORTHERN MONTANA

The finely arenaceous and siliceous purple, gray, and greenish shales of the Hector formation are of the same general character as those beneath the basal Cambrian conglomerate in Montana,[4] except that the pre-Cambrian shales in Montana are more distinctly arenaceous. The shales and sandstones of this series extend north from the Montana-Alberta international boundary to about 30 miles south of Crow Nest Pass, where they are cut off by faults that bring the Carboniferous and Cretaceous formations against them either by overlap or faulting. It is highly probable that pre-Cambrian rocks will be found not far north of Crow Nest Pass and west of the known Cretaceous and Carboniferous rocks; also in the valley of the Kootanie River, east of the Brisco and Stanford ranges. There

[4] Bull. Geol. Soc. America, vol. 17, 1906, Algonkian Formations of Montana, p. 3, *2a* of section.

is a large and interesting field for exploration in this region and north to the known Cambrian rocks of the Kicking Horse-Bow Valley section. With the data now available there should be little difficulty in mapping the pre-Cambrian, Cambrian, and post-Cambrian rocks.

With our present information the Hector and Corral Creek formations may be correlated in stratigraphic position with the Camp Creek and Kintla-Sheppard series of the Montana Algonkian, which are above the great Siyeh limestone.[5] The Bow Valley section does not extend down to the horizon of any massive pre-Cambrian limestone, but the fragments of limestone in the conglomerates of the Hector formation indicate the presence of subjacent limestones that were so situated as to be eroded by streams or shore waves when the sediments of the Hector formation were being deposited.

RÉSUMÉ

The object of this brief paper is to call attention to the presence in the Bow Valley, Alberta, of unaltered sedimentary strata of pre-Cambrian age. They lie unconformably beneath the Cambrian and are non-fossiliferous, as far as known. The formation names Hector and Corral Creek are proposed for them, and they are correlated with the Camp Creek and Kintla-Sheppard series of arenaceous rocks which lie beneath the Cambrian and above the Siyeh limestone in Montana, southwestern Alberta, and southeastern British Columbia.

[5] Bull. Geol. Soc. America, vol. 17, 1906, p. 18.

[illegible]